DOCUMENT RESUME

ED 070 909 AC 014 051

TITLE	Speed, Acceleration, and Velocity: Level II, Unit 9, Lesson 1; Force, Mass, and Distance: Lesson 2; Types of Motion and Rest: Lesson 3; Electricity and Magnetism: Lesson 4; Electrical, Magnetic, and Gravitational Fields: Lesson 5; The Conservation and Conversion of Matter and Energy: Lesson 6; Simple Machines and Work: Lesson 7; Gas Laws: Lesson 8; Principles of Heat Engines: Lesson 9; Sound and Sound Waves: Lesson 10; Light Waves and Particles: Lesson 11; Program. A High.....
INSTITUTION	Manpower Administration (DOL), Washington, D. C. Job Corps.
REPORT NO	PM-431-61; PM-431-62; PM-431-63; PM-431-64; PM-431-65; PM-431-66; PM-431-67; PM-431-68; PM-431-69; PM-431-70; PM-431-71; PM-431-72
PUB DATE	Nov 69
NOTE	433p.
EDRS PRICE	MF-$0.65 HC-$16.45
DESCRIPTORS	*Academic Education; Achievement Tests; *Autoinstructional Aids; *Course Content; Credit Courses; *General Education; *Independent Study; Physics; Secondary Grades

ABSTRACT

This self-study program for high-school level contains lessons on: Speed, Acceleration, and Velocity; Force, Mass, and Distance; Types of Motion and Rest; Electricity and Magnetism; Electrical, Magnetic, and Gravitational Fields; The Conservation and Conversion of Matter and Energy; Simple Machines and Work; Gas Laws; Principles of Heat Engines; Sound and Sound Waves; Light Waves and Particles; and The Behavior of Light Rays. Each of the lessons concludes with a Mastery Test to be completed by the student. (DB)

ED 070909

PM 431 - 61

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ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

SPEED, ACCELERATION, AND VELOCITY

LEVEL: II
UNIT: 9
LESSON: 1

AC014051

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

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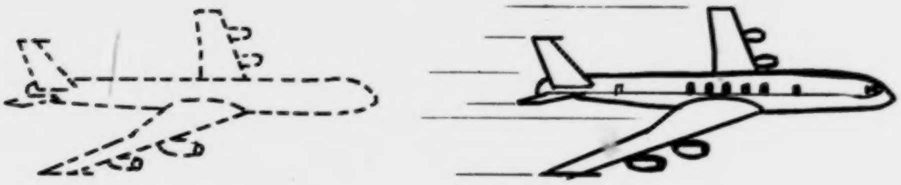
You are about to begin your second excursion into the Land of Physics. During your first visit, you learned many of the basic notions that are deeply embedded in a study of the physical world. You learned about matter and energy, atoms and molecules, fission and atomic fusion.

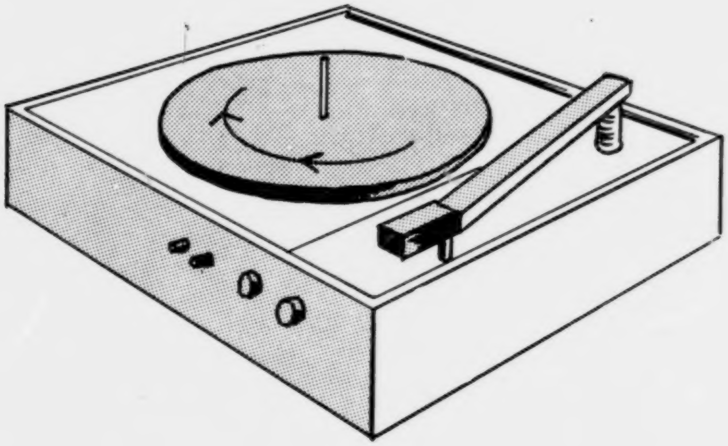
Now you are ready to begin extending your knowledge from these fundamentals to many specific areas of study about the physical world. You will learn a great deal about the motion of matter, how it is measured, how scientists talk about it in words with highly restricted definitions. You will learn about light and sound waves: how they travel, how they are produced, how you perceive them. You will also learn about gas laws and about heat...but never mind, for you are about to begin your learning visit. There is no need to describe what will soon be obvious to you.

The important thing to realize is that man studies the physical world in order to control those parts of it that he wants to, to turn it so that it works for him, so that he is not at its mercy. He constructs theories, and tests them, and if they are true, he can say they are true for all time and all space, not just for today, and not just for him. And all study of this nature begins with a person, like you, who sees and hears, and has his own built in sensing devices, and he tries to extend them...to the atom, the molecule, to the billions of miles that lie in outer space. And it is in this extension of self down into the deep core of all matter and out into the blindness of silent space that is the measure of the desire and the success with which men can learn and grow, and expand their worlds into eternities.

Time completed ________________

PANEL 1



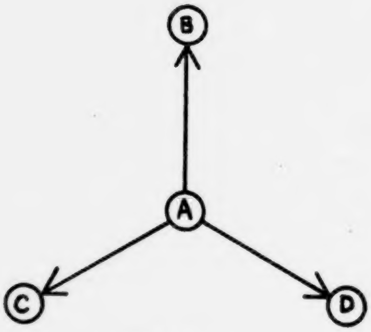


1. COMPARE the following statements: The car moved north by northeast at the rate of 45 miles per hour. The car moved because the turning of the wheels applied a force to the body of the car. The first statement describes how a car moved and the second statement explains why the car moved. How to describe the motion of objects and how to explain the causes of their motion are two different branches of the overall study of motion. In this lesson, you will learn the fundamentals of describing the motion of objects. Later lessons will deal with the causes of motion. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
2. REFER TO PANEL 1 Panel 1 illustrates the motion of an airplane and the turntable of a phonograph. The airplane is: ☐ moving in a straight line ☐ moving from place to place ☐ spinning around ☐ staying in one place The turntable is: ☐ moving in a straight line ☐ moving from place to place ☐ spinning around ☐ staying in one place	moving in a straight line moving from place to place spinning around staying in one place

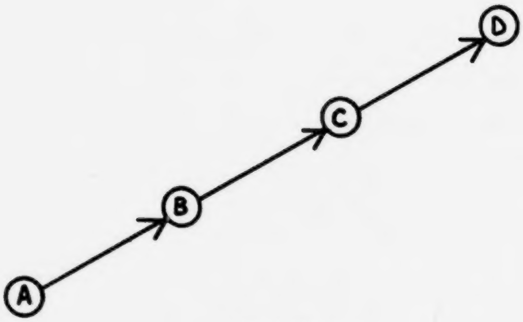
3.	
When an object moves in a straight line from place to place, its motion is described as translational.	
When an object spins around in one place, its motion is described as rotational.	
REFER TO PANEL 1	
The motion of the airplane is:	
☐ rotational	
☐ translational	translational
The motion of the phonograph's turntable is:	
☐ rotational	rotational
☐ translational	
4.	
The term translational motion refers to an object:	
☐ moving from place to place	moving from place to place
☐ moving in a straight line	moving in a straight line
☐ spinning around	
☐ staying in one place	
The term rotational motion refers to an object:	
☐ moving from place to place	
☐ moving in a straight line	
☐ spinning around	spinning around
☐ staying in one place	staying in one place

5. In the remainder of this lesson, and in the next few lessons, you will study translational motion. Rotational motion will be discussed in lesson 3 of this series. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
6. The car moved due east. The car moved twenty miles. The two statements above describe the translational movement of a car. The first statement states: ☐ how far the car moved ☐ how fast the car moved ☐ which way the car moved The second statement states: ☐ how far the car moved ☐ how fast the car moved ☐ which way the car moved	which way the car moved how far the car moved

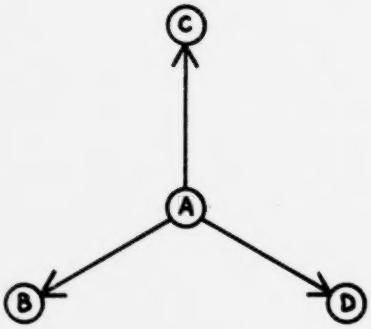
PANEL 2



DRAWING 1



DRAWING 2



DRAWING 3

7.

REFER TO PANEL 2

Panel 2 has three drawings. LOOK AT Drawing 1.

Imagine a small object located at position A. Suppose you are told that the object is to be moved one inch, but you are not told which way the object is to be moved. With this information, what could you say about the new position of the object?

☐ The new position may be B, C, or D.
☐ The new position will be B.
☐ The new position will be C.
☐ The new position will be D.

The new position may be B, . . .

Thus, when you are told how far an object is to be moved, but not which way, you:

☐ can say what the new position will be
☐ cannot say what the new position will be

cannot say what the new . . .

8.

REFER TO PANEL 2

Now LOOK AT Drawing 2.

Again imagine a small object located at position A. Suppose you are told that the object is to be moved toward the upper right-hand corner of the Panel, but you are not told how far. With this information, what could you say about the new position of the object?

☐ The new position may be B, C, or D.
☐ The new position will be B.
☐ The new position will be C.
☐ The new position will be D.

The new position may be B, ...

Thus, when you are told which way an object is to be moved, but not how far, you:

☐ can say what the new position will be
☐ cannot say what the new position will be

cannot say what the new . . .

9. REFER TO PANEL 2 LOOK AT Drawing 3. Suppose, this time, that you are told that the object is to be moved one inch toward the lower left-hand corner of the Panel. With this information, what could you say about the new position of the object? ☐ The new position may be B, C, or D. ☐ The new position will be B. ☐ The new position will be C. ☐ The new position will be D. Thus, when you are told both how far and which way an object is to be moved, you: ☐ can say what the new position will be ☐ cannot say what the new position will be	The new position will be B. can say what the new . . .
10. In order to determine the new position of an object relative to its old position, you must know: ☐ both how far and which way it has moved ☐ neither how far nor which way it has moved ☐ only how far it has moved ☐ only which way it has moved	both how far and which . . .

11.

The term distance refers to how far an object has moved.
For example: He drove the car for a distance of 180 miles.

The term direction refers to which way an object has moved.
For example: The plane flew in an easterly direction.

The term displacement refers to the new position of an object relative to its old position.
For example: The gun battery was displaced 3 1/2 miles to the west of its first position.

When you know the distance of an object's movement, but not the direction, you:

- ☐ can determine the displacement
- ☐ cannot determine the displacement

When you know the direction of an object's movement, but not the distance, you:

- ☐ can determine the displacement
- ☐ cannot determine the displacement

When you know both the distance and the direction of an object's movement, you:

- ☐ can determine the displacement
- ☐ cannot determine the displacement

cannot determine the . . .

cannot determine the . . .

can determine the . . .

12.	
Direction refers to:	
☐ how far an object moves ☐ which way an object moves	which way an object moves
Distance refers to:	
☐ how far an object moves ☐ which way an object moves	how far an object moves
In order to determine the displacement of an object, you must know:	
☐ more than the distance and direction of movement	
☐ only the direction of movement	
☐ only the distance and direction of movement	only the distance and . . .
☐ only the distance of movement	
13.	
Do the terms distance and displacement have the same meaning?	
☐ yes ☐ no	no
Can you explain your answer?	Distance means how far. Displacement means how far and which way. (or equivalent response)

14. Suppose a car is moving at the rate of 30 miles per hour. This means that the car will move 15 miles in half an hour. That is, when you know how fast an object is moving, you: ☐ can say how far it will move in a given period of time ☐ cannot say how far it will move in a given period of time	can say how far it will . . .
15. The bird flew at the rate of 20 miles per hour. The bird flew due south at the rate of 20 miles per hour. The two statements above describe the flight of a bird The first statement states: ☐ how fast the bird flew ☐ which way the bird flew The second statement states: ☐ how fast the bird flew ☐ which way the bird flew	how fast the bird flew how fast the bird flew which way the bird flew

16. The term speed refers to how fast an object moves. When the description of how fast an object moves also states which way the object moves, the description is called velocity. Suppose you know the period of time during which an object moves. If you also know its speed, you can determine:	
☐ how far it moves ☐ which way it moves	how far it moves
If you know its velocity, you can determine: ☐ how far it moves ☐ which way it moves	how far it moves which way it moves
Recall what you learned about displacement. In order to determine the displacement of an object, you must know: ☐ how far it moves ☐ which way it moves	how far it moves which way it moves
That is, you must know its: ☐ speed ☐ velocity	velocity
17. Speed refers to: ☐ how fast an object moves ☐ which way an object moves	how fast an object moves
Velocity refers to: ☐ how fast an object moves ☐ which way an object moves	how fast an object moves which way an object moves

18.	
Do the terms speed and velocity have the same meaning?	
☐ yes ☐ no	no
Can you explain your answer?	Speed means how fast. Velocity means how fast and which way. (or equivalent response)
19.	
The speed of the car changed from 40 miles per hour to 60 miles per hour. The speed of the car changed from 40 miles per hour to 20 miles per hour. The direction of the car changed from south to southeast.	
The three statements above describe the movement of a car.	
The first statement indicates: ☐ a decrease in the car's speed ☐ an increase in the car's speed	an increase in the car's speed
The second statement indicates: ☐ a decrease in the car's speed ☐ an increase in the car's speed	a decrease in the car's speed
The third statement indicates a change in: ☐ direction ☐ speed	direction

20. Recall that velocity refers to both the speed and the direction of an object's movement. Thus, an increase in the speed of an object would mean: ☐ a change in velocity ☐ no change in velocity	a change in velocity
A decrease in the speed of an object would mean: ☐ a change in velocity ☐ no change in velocity	a change in velocity
A change in the direction of an object would mean: ☐ a change in velocity ☐ no change in velocity	a change in velocity
21. The velocity of an object changes when there is/are: ☐ a change in direction ☐ a decrease in speed ☐ an increase in speed	a change in direction a decrease in speed an increase in speed

PANEL 3

1. The speed of the car changed from 25 to 50 miles per hour.

2. The speed of the car changed from 25 to 50 miles per hour in 5 minutes.

3. The speed of the car changed from 70 to 40 miles per hour in 17 seconds.

4. The speed of the car changed from 70 to 40 miles per hour.

5. The direction of the car changed from west to northwest.

6. The direction of the car changed from west to northwest in 3 1/2 hours.

22.	
REFER TO PANEL 3	
Panel 3 lists six statements concerning the movement of a car.	
Consider the first two statements. The first statement describes:	
☐ not only how much the speed of the car increased, but also how quickly	
☐ only how much the speed of the car increased	only how much the speed . . .
The second statement describes:	
☐ not only how much the speed of the car increased, but also how quickly	not only how much the . . .
☐ only how much the speed of the car increased	

23.	
REFER TO PANEL 3	
Consider the next two statements. The third statement describes:	
☐ not only how much the speed of the car decreased, but also how quickly	not only how much the . . .
☐ only how much the speed of the car decreased	
The fourth statement describes:	
☐ not only how much the speed of the car decreased, but also how quickly	
☐ only how much the speed of the car decreased	only how much the speed . . .
Consider the last two statements. The fifth statement describes:	
☐ not only how much the direction of the car changed, but also how quickly	
☐ only how much the direction of the car changed	only how much the . . .
The sixth statement describes:	
☐ not only how much the direction of the car changed, but also how quickly	not only how much the . . .
☐ only how much the direction of the car changed	
24.	
REFER TO PANEL 3	
A change in velocity is described in:	
☐ all statements	all statements
☐ no statements	
☐ some statements	

25.

You are probably familiar with the terms acceleration and deceleration. They are everyday words to refer to an increase and decrease in the speed of an object.

For example, when we say that a car accelerated to 60 miles an hour we mean that the speed of the car increased to 60 miles per hour.

NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

26.

In the study of physics, the term acceleration refers not only to how much the speed of an object increases, but also to how quickly. And acceleration refers not only to an increase in speed, but also to a decrease* in speed or to a change in direction.

For example, the following statements describe the acceleration of a train:

> The speed of the train decreased from 90 to 80 miles per hour in 15 seconds.
>
> The direction of the train changed from north to northwest in 5 minutes.

REFER TO PANEL 3

Which statements on the Panel describe the acceleration of the car?

☐ Statement 1	
☐ Statement 2	Statement 2
☐ Statement 3	Statement 3
☐ Statement 4	
☐ Statement 5	
☐ Statement 6	Statement 6

---

* Thus the scientific meaning of acceleration includes the meaning of deceleration.

27.	
In the study of physics, the term acceleration refers to:	
☐ how much and how quickly the direction of an object changes	. . . direction of an object . . .
☐ how much and how quickly the speed of an object decreases	. . . an object decreases
☐ how much and how quickly the speed of an object increases	. . . an object increases
☐ only how much and how quickly the direction of an object changes	
☐ only how much the speed of an object decreases	
☐ only how much the speed of an object increases	
28.	
In everyday usage, acceleration refers to:	
☐ a change in direction	
☐ a decrease in speed	
☐ an increase in speed	an increase in speed
In scientific language, the term acceleration may refer to any of the above, that is, to:	
☐ any change in velocity	any change in velocity
☐ only some changes in velocity	

29.

MATCH the columns below to compare the everyday usage of the terms acceleration and deceleration with the scientific use of the term acceleration:

A. how much and how quickly the direction of an object changes

B. how much and how quickly the speed of an object decreases

C. how much and how quickly the speed of an object increases

D. only how much and how quickly the direction of an object changes

E. only how much the speed of an object decreases

F. only how much the speed of an object increases

1. _____	acceleration in everyday usage	1. F
2. _____	acceleration in scientific language	2. A, B, C
3. _____	deceleration in everyday usage	3. E

30.

MATCH the columns below to indicate the definition of each term listed on the right:

A. a description of how fast and in what direction an object travels

B. a description of how far an object travels

C. a description of how fast an object travels

D. a description of how much and how quickly the velocity of an object changes

E. a description of the new position of an object relative to its old position

1. _____ acceleration
2. _____ displacement
3. _____ distance
4. _____ speed
5. _____ velocity

1. D
2. E
3. B
4. C
5. A

Time completed ______________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
TRANSLATIONAL MOTION	refers to movement in a straight line from place to place; EXAMPLE: the motion of an airplane.
ROTATIONAL MOTION	refers to a spinning around movement; EXAMPLE: the motion of a phonograph's turntable.
DISTANCE	refers to how far an object has moved.
DIRECTION	refers to which way an object has moved.
DISPLACEMENT	refers to the new position of an object relative to its old position.
SPEED	refers to how fast an object is moving.
VELOCITY	refers to the speed and the direction of a moving object.
ACCELERATION	In scientific language: refers to how much the speed of an object increases or decreases; also refers to how quickly the speed is increased or decreased. In everyday language: acceleration refers to how much the speed of an object increases.
DECELERATION	In scientific language: the notion of deceleration is included in the notion of acceleration. In everyday language: deceleration refers to how much the speed of an object decreases.

MASTERY TEST

Time started ______________

1. The earth spins on its axis and revolves around the sun. The movement of the earth may be described as:

   a. ☐ both rotational and translational
   b. ☐ neither rotational nor translational
   c. ☐ only rotational
   d. ☐ only translational

2. If a car slows down and makes a U-turn, there is:

   a. ☐ a change in velocity
   b. ☐ no change in velocity

   because:

   a. ☐ the direction of the car is unchanged
   b. ☐ the speed of the car is unchanged
   c. ☐ the speed is decreased and the direction is changed
   d. ☐ the speed is increased and the direction is changed

3. In the study of physics, the term acceleration:

   a. ☐ does not refer to the everyday meaning of the word deceleration
   b. ☐ does not refer to a change in the direction of movement of an object
   c. ☐ may refer to a decrease in the speed of an object
   d. ☐ refers only to an increase in the speed of an object

NOTE: Skip one(1) page to find page 25 and continue with question 4.

4. A car is traveling at the rate of 50 miles per hour. In 5 minutes it changes its direction from east to southwest. This change is one of:

a. ☐ acceleration

b. ☐ speed

c. ☐ velocity

d. ☐ all of these

Time completed _______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

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ED 070909

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ADVANCED
GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

FORCE, MASS, AND DISTANCE
LEVEL: II
UNIT: 9
LESSON: 2

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
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1.

TRANSLATIONAL DYNAMICS

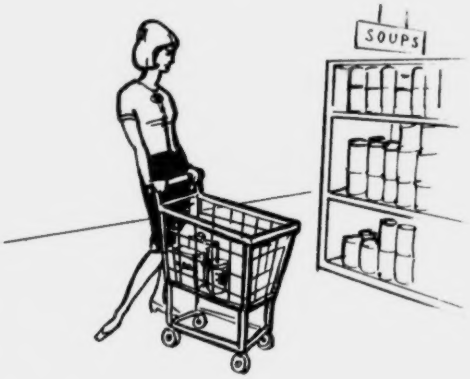
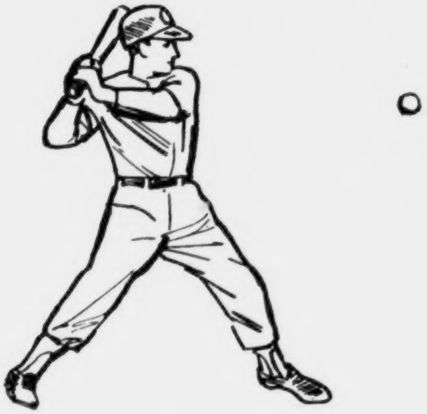
We see and work with moving objects every day of our lives. Usually we do not stop to think about why they move as they do.

For thousands of years, men were ignorant of the causes of motion. Then, some 300 years ago, Sir Isaac Newton applied scientific methods to the study of everyday events. The "laws of motion" he worked out are still used by engineers and physicists -- in everything from the design of buildings to the planning of rocket flights to the moon.

In this lesson you will learn the basic laws of motion and how they apply to the world around us.

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

2.	
 A	
In A, the woman wants to load her cart with canned soup. Will the cart move over to the shelf by itself? ☐ yes ☐ no	no
 B	
In B, the batter is looking at a good pitch. He doesn't want to let it go by him. What will happen if he keeps standing there looking at it? ☐ It will stop. ☐ It will keep going on past him.	It will keep going on past him.

3. The examples in the last frame illustrate obvious rules. An object at rest (standing still) will: ☐ remain at rest unless something moves it ☐ start to move by itself A moving object will: ☐ continue to move unless something stops it ☐ stop moving by itself	remain at rest unless . . . continue to move unless . . . * *We know that moving objects do finally come to a stop. You will learn what circumstances are responsible for this in a later lesson. For the present, it is sufficient to know that objects do not stop by themselves.
4. A car is headed north along a road. The driver wants to turn east at a corner. The car will turn east: ☐ only if the driver steers it that way ☐ without the driver doing anything	only if the driver steers it that way

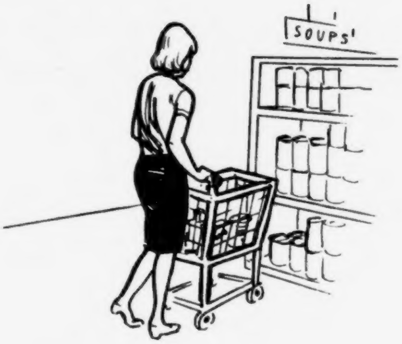
5.	
Your own experience tells you that:	
☐ moving objects tend to change direction by themselves	
☐ moving objects tend to keep moving in the same direction	. . . in the same direction
☐ moving objects tend to move by themselves	
☐ objects at rest tend to move by themselves	
☐ objects at rest tend to stay at rest	. . . stay at rest
6.	
The tendency of moving objects to keep moving in a straight line - that is, without changing direction - and of objects at rest to remain at rest, is called inertia.	
Which of these is/are an example(s) of inertia?	
☐ A ball headed for a window will hit the window unless it is caught or knocked aside.	A ball headed for a window . . . .
☐ Your bed stays where it is until it is moved.	Your bed stays where it is . . . .

7. Which of the following examples illustrate the physical idea of inertia? ☐ A car will not go around a corner unless you change its direction by steering it. ☐ A hard-hit baseball will keep going into the outfield if no one stops it. ☐ Grass will not grow unless it gets sun and water. ☐ If a billiard ball lying on a pool table is not pushed by a cue or another ball, it will not move. ☐ If a girl never cuts her hair, it will grow down to her shoulders.	A car will not go around . . . . A hard-hit baseball will keep . . . . If a billiard ball lying on a . . . .
8. REVIEW FRAME The velocity of an object describes: ☐ only its direction ☐ only its speed ☐ both its speed and its direction	both its speed and its direction

9.	
Ordinarily, we think of velocity only in terms of moving objects. But scientists find it useful to talk about velocity for objects at rest, as well.	
What would you say is the speed of a motionless object?	
☐ 0 miles per hour	0 miles per hour
☐ 1/2 mile per hour	
☐ 10 miles per hour	
What is the direction of motion of an object standing still?	
☐ east	
☐ north	
☐ south	
☐ west	
☐ none of the above	none of the above
The velocity of an object at rest is:	
☐ less than zero	
☐ more than zero	
☐ zero	zero
10.	
When we put an object at rest into motion, we increase its velocity from zero. Therefore, we:	
☐ change its velocity	change its velocity
☐ do not change its velocity	
When we stop a moving object, velocity:	
☐ decreases to zero	decreases to zero
☐ does not change	
☐ increases to zero	
When we change the direction without changing the speed of a moving object, velocity:	
☐ changes	changes
☐ does not change	

11. Acceleration is: ☐ any change in velocity ☐ only change in direction ☐ only decrease in speed ☐ only increase in speed	any change in velocity
What one word describes putting an object at rest into motion, stopping a moving object, and changing the direction of a moving object? ________________	acceleration
12. Inertia is the tendency of: ☐ all objects to change velocity	
☐ moving object to keep moving in the same direction	moving object to keep moving . . .
☐ objects at rest to stay at rest	objects at rest to stay at rest
You can say, then, that inertia is the tendency of objects to: ☐ accelerate ☐ resist acceleration	resist acceleration

13.



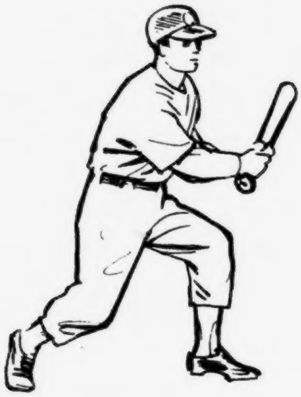
A

From your own experience, you know that you overcome inertia by applying some kind of force to an object.

In A, the woman overcomes the resistance of the shopping cart to acceleration by (doing what?)

____

pushing it (or equivalent response)



B

A pitched ball resists change in its direction of motion. In B, the batter overcomes its inertia by (doing what?)

____

hitting it (or equivalent response)

14.

In everyday usage, the word force is associated with violence -- ("We won our freedom by force of arms") -- or with compelling someone to do something -- ("I was forced to agree with him").

Like several other terms you have learned, force has a more exact meaning in science. In relation to motion, force is an influence on a body which tends to produce a change in movement. In other words, force is whatever overcomes inertia.

In the scientific sense, which of the following are examples of force?

- ☐ hitting a baseball
- ☐ pulling a wagon
- ☐ pushing a baby carriage
- ☐ robbing someone at gunpoint

hitting a baseball
pulling a wagon
pushing a baby carriage

15.

Newton's first law of motion is a statement in scientific terms of the rules we have been discussing:

> "A body at rest tends to remain at rest and a body in motion tends to remain in motion with constant velocity unless acted upon by an external force."*

Which one statement below says essentially the same thing?

- ☐ All objects (in motion or at rest) have inertia.
- ☐ All objects (in motion or at rest) have inertia, which can be overcome only by applying force.
- ☐ Bodies at rest resist acceleration.
- ☐ Moving objects resist changes in velocity.

. . . by applying force.

*The English scientist Isaac Newton developed the laws of motion three hundred years ago.

16. Newton's first law of motion is called the law of inertia. What does it state? (CHECK the best definition.) ☐ Bodies at rest and in motion resist acceleration. ☐ Force is required to overcome inertia. ☐ Inertia, which all bodies have, is overcome by the application of force.	Inertia, which all bodies . . . .
17. According to Newton's law of inertia, which of the following statements is true? ☐ Bodies at rest stay at rest forever. ☐ Changing the velocity of an object requires the application of force. ☐ Objects sometimes accelerate without any applied force. ☐ The velocity of a moving body cannot be changed.	Changing the velocity of an . . . .
18. All objects, we have seen, have inertia. Now let us see whether all objects have the same inertia; that is, do all bodies resist acceleration to the same extent? Again your own experience will give you the answer. Which is harder to push? ☐ a baby carriage ☐ an automobile Which is harder to stop? ☐ a cannonball ☐ a ping-pong ball	an automobile a cannonball

19.	
An automobile has greater inertia than a baby carriage. A cannonball has greater inertia than a ping-pong ball.	
You can see that, at a given velocity:	
☐ heavy objects have more inertia ☐ light objects have more inertia	heavy objects have more inertia
20.	
Inertia, like mass, is a property of all objects. Let us see how the two properties are related, no velocity.	
Heavier objects have: ☐ less inertia ☐ more inertia	more inertia
Heavier objects have: ☐ less mass ☐ more mass	more mass
Objects with more mass have: ☐ less inertia ☐ more inertia	more inertia
21.	
How are inertia and mass* related, at a given velocity?	
☐ The greater the mass of an object, the greater its inertia.	. . . the greater its inertia.
☐ The greater the mass of an object, the less its inertia.	
☐ They are not related at all.	
A slowly rolling bowling ball and a speeding bullet:	
☐ can have equal inertia ☐ cannot have equal inertia	can have equal inertia
*Mass, on earth, equals weight.	

22. You know that objects that have different mass can have equal inertia if their velocities are different. You also know that the greater the inertia, the more force you need to overcome it. For example, which takes more strength to move? ☐ an empty wheelbarrow ☐ a wheelbarrow full of bricks	a wheelbarrow full of bricks
23. Force can be measured in terms of pounds of pull. For example, a force of only 5 pounds may be needed to move a child's wagon, while 50 pounds of pull may be needed to move a heavy box. Suppose you apply a force (a pull) of 25 pounds to the child's wagon. What will happen? ☐ It will move very fast. ☐ It will move very slowly. ☐ It will not move at all.	It will move very fast.
24. Using a large force on a light object gets it moving faster. For example: 5 lbs. of pull increases the wagon's speed from 0 miles per hour to 1/2 mile per hour in one second. 25 lbs. of pull increases the wagon's speed from 0 miles per hour to 2 1/2 miles per hour in the same time. Applying greater pull: ☐ decreases speed ☐ increases speed ☐ has no effect on acceleration	increases speed

25. For an object with a given mass, you can increase its speed: ☐ by decreasing the force ☐ by increasing the force ☐ without changing the force	by increasing the force
26. Suppose you want to accelerate two objects of different masses in the same way. Which requires more force? ☐ object with greater mass ☐ object with less mass	object with greater mass
27. How are force and mass related? ☐ The greater the mass, the smaller the force needed. ☐ The greater the mass, the greater the force needed.	The greater . . . greater . . .
How are force and acceleration related? ☐ To get more speed, you need less force. ☐ To get more speed, you need more force.	. . . you need more force.

28.

Newton studied the relationship between force, mass, and acceleration. He used the results of his experiments to formulate his second law of motion:

> "A single force acting on a body will produce an acceleration such that the force is equal to the product of the body's mass times its acceleration."

In mathematical form, the law is written:

$$F = m \times a$$

where F is the force acting on a body whose mass is m, and a is the resulting acceleration.

In words, this mathematical formula states:

- ☐ Acceleration equals mass times force.
- ☐ Force equals mass times acceleration.
- ☐ Mass equals force times acceleration.

Force equals mass times . . . .

29.

$$\underset{\text{(force)}}{F} = \underset{\text{(mass)}}{m} \times \underset{\text{(acceleration)}}{a}$$

Let us see whether this statement of Newton's second law of motion agrees with our experience.

According to the law, a force F gives an acceleration a to a body of mass m. Suppose we want to give the same acceleration to a heavier object -- a body with mass $2m$ (twice as much as m).

What happens to the right-hand side of the equation (mass times acceleration)?

- ☐ It decreases.
- ☐ It increases.
- ☐ It stays the same.

It increases.

Since force (F) equals mass times acceleration, what does the law tell us about the force required?

- ☐ It must be greater.
- ☐ It must be smaller.
- ☐ It stays the same.

It must be greater.

30. $F = m \times a$ This formula -- the mathematical statement of Newton's second law of motion -- tells us that to produce the same acceleration in an object of greater mass we must increase the applied force. Suppose, instead, that we decrease F (the force) and leave a (the acceleration) alone. What happens to m (the mass)? Does this change the amount of mass that can be affected by the same force? (THINK: The product, F, decreases. One of the quantities multiplied stays the same. How must the other quantity change?)	
☐ Quantity of mass must be less. ☐ Quantity of mass must be more. ☐ Quantity of mass stays the same.	Quantity of mass must be less.
In everyday terms we would say that less force is needed to produce the same result on a:	
☐ heavier object ☐ lighter object ☐ object of the same weight	lighter object
31. The examples in the last two frames demonstrate that $F = m \times a$ agrees with what we know of the world. It implies that:	
☐ a greater force will give the same object greater acceleration	a greater force will give . . .
☐ less force will give the same object greater acceleration	
☐ lighter objects require less force to give them the same acceleration as heavy objects	. . . less force to give . . .
☐ lighter objects require more force to give them the same acceleration as heavy objects	

32. Newton's second law of motion states: "A single force acting on a body will produce an acceleration such that the force is equal to the product of the body's mass and its acceleration." Using F for force, m for mass and a for acceleration, GIVE the mathematical form of the law: ________________	$F = m \times a$
33. What is the mathematical formula for Newton's second law of motion? ☐ $a = m \times F$ ☐ $F = m \times a$ ☐ $m = F \times a$	$F = m \times a$
34. $F = m \times a$ All the terms in a mathematical formula, such as this one, can be expressed as quantities. By substituting quantities for the letters, we can apply the formula to real problems. Some of the quantities you would use in this formula are of a special kind, because they are quantities that have direction. Acceleration is an example of this kind of quantity. Mass, on the other hand, is a quantity that does not have direction. In the next few frames, you will learn the names for the two different kinds of quantities, and important examples of each. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

35. Some quantities have magnitude, meaning that we can compare two measures and say which is larger or smaller. For example, you can measure the mass of two objects by weighing them on the same scale to determine which one has a greater mass.	
Can you compare two distances by measuring their lengths? ☐ yes ☐ no	yes
Can you compare the speed of two objects by measuring how far they go in a given time? ☐ yes ☐ no	yes
Which quantities have magnitude? ☐ distance ☐ mass ☐ speed	distance mass speed
36. Several quantities have direction, as you already know. Which of the following have direction? ☐ acceleration ☐ displacement ☐ distance ☐ speed ☐ velocity	acceleration displacement velocity
37. Acceleration, displacement, and velocity have direction. You can also compare two measures of these quantities to see which is greater. Do acceleration, displacement, and velocity have magnitude? ☐ yes ☐ no	yes

38.

CHECK one or both columns for each quantity listed:

	Have magnitude	Have direction	Have magnitude	Have direction
acceleration	☐	☐	☒	☒
displacement	☐	☐	☒	☒
distance	☐	☐	☒	☐
mass	☐	☐	☒	☐
speed	☐	☐	☒	☐
velocity	☐	☐	☒	☒

39.

A quantity having only magnitude is called a scalar quantity because it can be completely described by measuring it on some kind of scale (such as a weighing scale or a ruler).

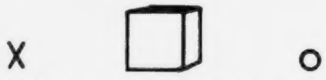
A quantity having magnitude and direction is called a vector quantity.

GIVE an example of a scalar quantity: ______________	distance or mass or speed
GIVE an example of a vector quantity: ______________	acceleration or displacement or velocity

40.

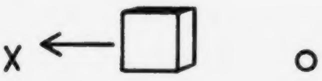
We noted before that a force can be measured in terms of pounds of pull. We know, then, that force has magnitude. Let us see whether force also has direction.

Below you see an object which will move slowly if you exert a pull of 20 pounds on it. Suppose you stand at the spot marked X and pull it toward you with 20 pounds of force. DRAW an arrow to show which way it will move:



Suppose instead that you stood at the spot marked by a circle when you pulled it toward you. Would it move the same way?

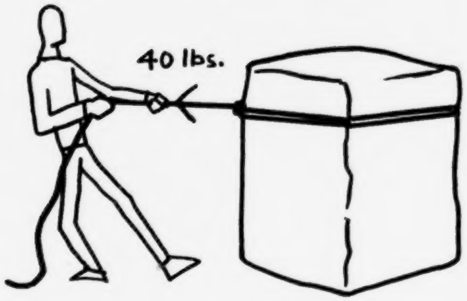
☐ yes
☐ no



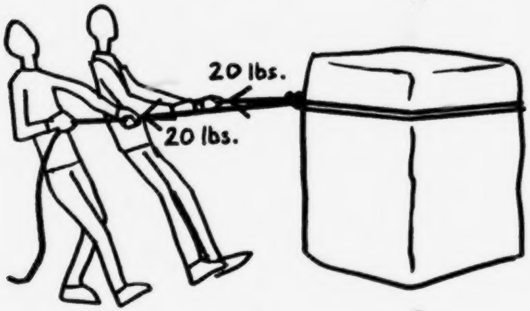
no

41.	
Obviously the direction in which a force is exerted makes a difference in the result.	
To completely describe a force you must state:	
☐ only its direction ☐ only its magnitude ☐ both its direction and its magnitude	both its direction and its magnitude
What kind of quantity is force?	
☐ a scalar quantity ☐ a vector quantity	a vector quantity
42.	
WRITE s next to the terms which refer to scalar quantities, and v next to the ones that refer to vector quantities.	
_____ acceleration	v
_____ displacement	v
_____ distance	s
_____ force	v
_____ mass	s
_____ speed	s
_____ velocity	v
NOTE NOTE NOTE NOTE	
Turn to back cover to find frame 43 on page 21.	

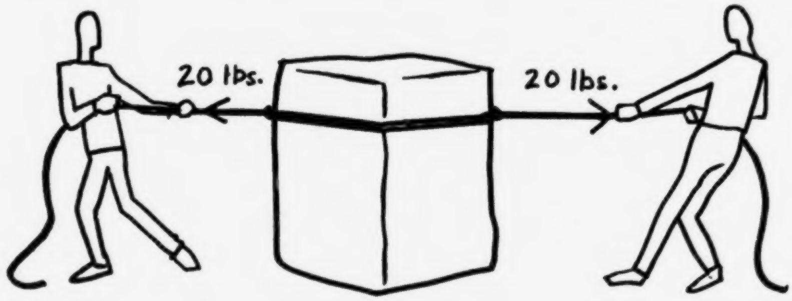
PANEL 1



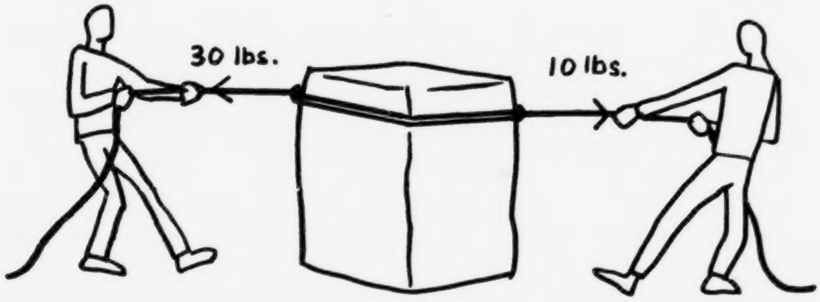
A


20 lbs.
20 lbs.

B


20 lbs.
20 lbs.

C


30 lbs.
10 lbs.

D

43.	
REFER TO PANEL 1 (Page 20).	
In A, we see a box being subjected to a single 40-lb. pulling force. This force gives an acceleration a to the box.	
In B, we see two men pulling the same box, each exerting 20 lbs. of force. Because they are pulling in the same direction, we can add the two forces to get the total force, _____ (how many?) lbs.	40
What acceleration will result in this case, compared to the acceleration a in the first case?	
☐ equal to a ☐ greater than a ☐ less than a, but not zero ☐ zero	equal to a
In C, we again see two men pulling the box, each with a force of 20 lbs. But here they are pulling in opposite directions. From your own experience, what will the resulting acceleration be?	
☐ equal to a ☐ greater than a ☐ less than a, but not zero ☐ zero	zero

44. REFER TO PANEL 1 When more than one force is acting on an object at one time, we must consider the result of the combined forces. Since force is a vector quantity, this result depends on the magnitude and direction of the individual forces. All the forces, taken together, are called the resultant force. What is the resultant force in B? ☐ less than 40 lbs., but not zero, to the left ☐ 40 lbs., to the left ☐ more than 40 lbs., to the left ☐ zero What is the resultant force in C? ☐ less than 40 lbs., but not zero, to the left ☐ 40 lbs., to the left ☐ more than 40 lbs., to the left ☐ zero	40 lbs., to the left zero
45. REFER TO PANEL 1 Now LOOK at D. The opposing forces are not equal. In which direction is the larger force pulling? ☐ to the left ☐ to the right What will be the direction of the resultant force? ________________ What will be the magnitude of the resultant force? ☐ less than 40 lbs., but not zero ☐ 40 lbs. ☐ more than 40 lbs. ☐ zero	to the left to the left less than 40 lbs., but not zero

46. When more than one force is applied to a body, the resultant force may be zero, or it may not be zero. It will be zero if: ☐ the forces are equal and in opposite directions ☐ the forces are equal and in the same direction ☐ the forces are not equal and are in opposite directions ☐ the forces are not equal and are in the same direction	the forces . . . opposite directions
47. Equal and opposite forces are acting on a body at rest. CHECK the true statements: ☐ The resultant force is not zero. ☐ The resultant force is zero. ☐ The body does not remain at rest. ☐ The body remains at rest.	The resultant force is zero. The body remains at rest.
48. F = m x a applies whether only one force, or several forces, act on a body at one time. Where more than one force is acting, F refers to the resultant force. In the following frames, you will learn how the direction of one force, or the resultant of several forces, affects a body's velocity. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

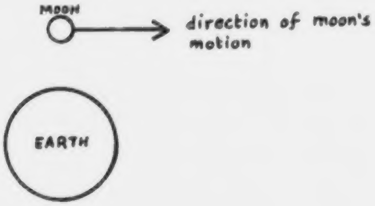
49.	
An airplane is flying due south at 300 miles per hour. A 40-mile-per-hour tail wind (blowing toward the south) comes up.	
What effect will it have?	
☐ change the plane's direction ☐ decrease the plane's speed to the south ☐ increase the plane's speed to the south ☐ no effect at all	increase the plane's speed . . .
Suppose, instead, that the wind is a 40-mile-per-hour head wind (blowing toward the north).	
What effect will it have?	
☐ change the plane's direction ☐ decrease the plane's speed to the south ☐ increase the plane's speed to the south ☐ no effect at all	decrease the plane's speed . . .
50.	
A force applied in the same direction as a body's direction of motion, or in the opposite direction, affects only the body's speed.	
A force on a moving body in the same direction:	
☐ decreases the body's speed ☐ increases the body's speed	increases the body's speed
A force on a moving body in the opposite direction:	
☐ decreases the body's speed ☐ increases the body's speed	decreases the body's speed

51.

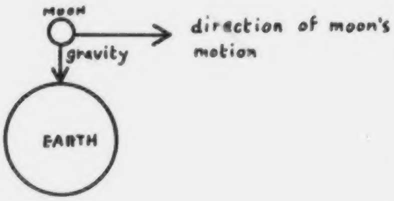
A force may act on a body in a direction different from, but not opposite to, the direction of motion.

The force of gravity (the "pull" of the earth) acts in this way on the moon.

At any particular moment, the moon's motion is really in a straight line:


MOON
direction of moon's motion
EARTH

But, at the same time, the force of the earth's gravity is exerting a pull toward the earth:

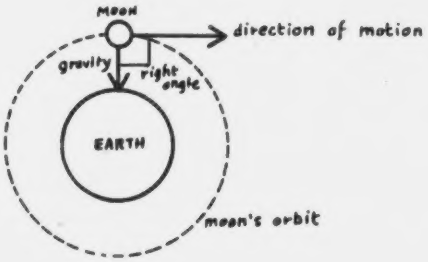

MOON
direction of moon's motion
gravity
EARTH

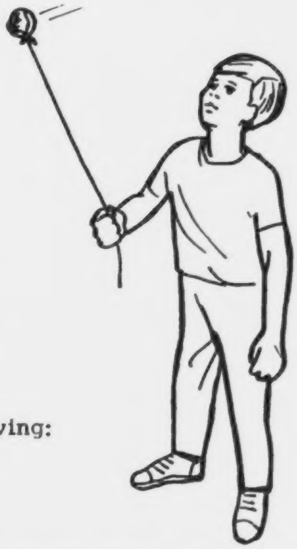
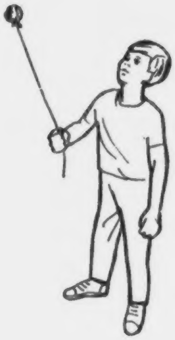
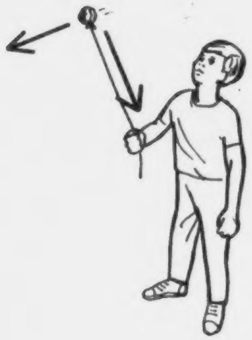
The result of the downward pull of the earth's gravity is to constantly change the direction of the moon's motion.

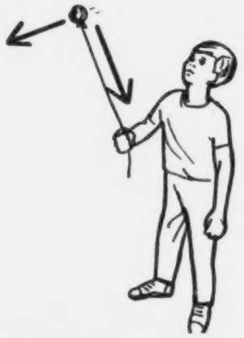
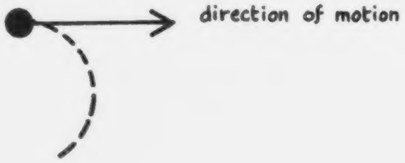
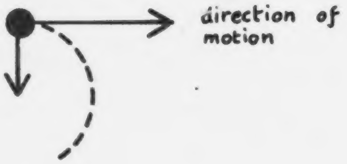
How does the moon move?

☐ in a curved path around the earth
☐ on a straight line out into space

in a curved path around the earth

52.	
 MOON direction of motion gravity right angle EARTH moon's orbit	
We have seen that the earth's pull (gravity) keeps the moon moving in its orbit (path) around the earth. The force of gravity does not change the speed with which the moon moves.	
In what direction is the force of gravity acting?	
☐ at right angles to the moon's motion, away from the center of the orbit (the earth)	
☐ at right angles to the moon's motion, toward the center of the orbit (the earth)	. . . toward the center of the . . .
☐ in the direction opposite to the moon's motion	
☐ in the same direction as the moon's motion	
Gravity accelerates the moon by:	
☐ changing its direction ☐ slowing it down ☐ speeding it up	changing its direction

53.  The stone in the picture is moving: ☐ in a circle ☐ in a straight line Suppose the string broke. The stone would move: ☐ in a circle ☐ in a straight line	in a circle in a straight line
54. At any moment, the direction of motion of the stone is in a straight line, as we see if the string breaks and the stone flies off. But the unbroken string exerts a force on the stone which causes it to move in a circle -- just as the force of gravity keeps the moon moving in orbit. DRAW arrows to show the stone's direction of motion and the direction of the force exerted by the string. 	

55.  The force which keeps the stone whirling around, instead of flying off, acts: ☐ at right angles to the direction of motion, away from the center (the boy) ☐ at right angles to the direction of motion, toward the center (the boy) ☐ in the direction opposite to the stone's motion ☐ in the same direction as the stone's motion	. . . motion, toward the center . . .
56. DRAW an arrow to represent a force which will make this object move along the dotted line:  	

57.

A satellite is circling the earth at constant speed.

CHECK the true statement:

- ☐ A resultant force of zero is acting on it.
- ☐ No force is acting on it.
- ☐ There is a force acting on it at right angles to its direction of motion, toward the center.
- ☐ There is a force acting on it at right angles to its direction of motion, away from the center.

. . . toward the center.

58.

MATCH the forces acting in various directions with their effects on a moving body.

A. changes body's direction

B. decreases body's speed

C. increases body's speed

D. makes body move in a curved path

1. _____ force acting in opposite direction to body's direction of motion

2. _____ force acting in same direction as body's direction of motion

3. _____ force acting at right angles to body's direction of motion

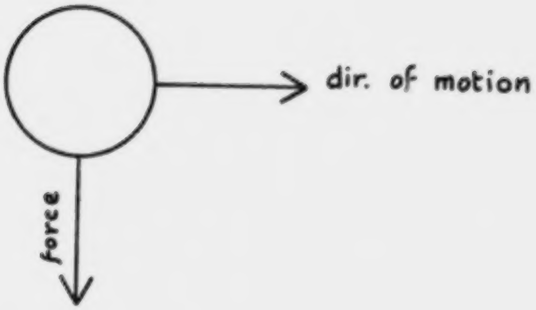
1. B

2. C

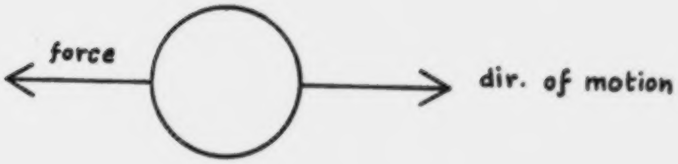
3. A, D

PANEL 2

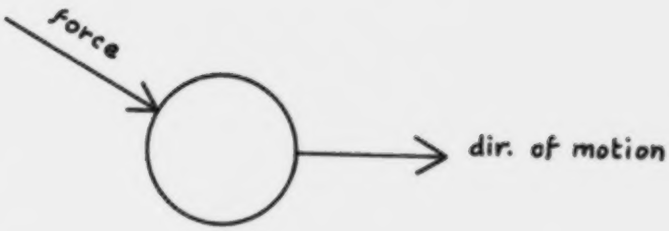
A.


dir. of motion
force

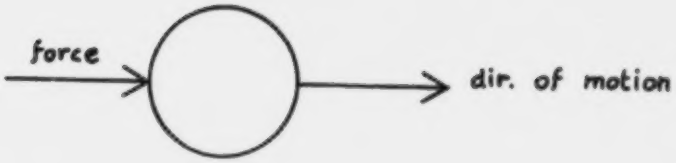
B.


force
dir. of motion

C.

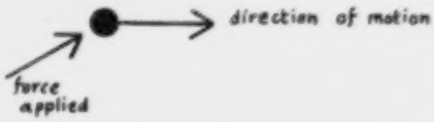

force
dir. of motion

D.


force
dir. of motion

59.

If a force acts in some other direction -- not at right angles, nor in the same or the opposite direction -- it will change both a body's speed and its direction.



How will the force shown accelerate the body?

☐ change its speed
☐ change its direction
☐ not at all

change its speed
change its direction

60.

REFER TO PANEL 2

Which diagram shows a force which will have each effect? (WRITE the letter of a diagram in the Panel next to each effect described.)

_____ only change direction of the body	A
_____ only decrease the body's speed	B
_____ only increase the body's speed	D
_____ change the body's direction and speed	C

61.

What effect does each force described have on a moving body? (CHECK the columns that apply.)

	Changes direction	Changes speed	direction	speed
1. force acting in same direction as motion	☐	☐	☐	☒
2. force acting in direction opposite to motion	☐	☐	☐	☒
3. force acting at right angles to motion	☐	☐	☒	☐
4. force acting in direction different from, but not opposite or at right angles to, motion	☐	☐	☒	☒

62.

The "laws of motion" you have been learning are basic rules that apply to many areas of physical science.

They are important not only in the study of moving objects, but in the study of stationary objects as well, such as buildings and bridges. In the final few frames of this lesson, you will see why.

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

63.	
REVIEW	
When more than one force is acting on a body at one time, Newton's second law of motion (F = m x a):	
☐ applies to the resultant force ☐ does not apply	applies to the resultant force
Under what conditions will a body at rest remain at rest?	
☐ if a non-zero resultant force is acting on it ☐ if a zero resultant force is acting on it ☐ if no forces are acting on it	if a zero resultant force . . . if no forces are acting on it
64.	
Can a body at rest remain at rest if forces are acting on it?	
☐ yes ☐ no	yes
EXPLAIN your answer.	If resultant force is zero, it will not be accelerated. (or equivalent response)

65.	
The study of forces acting on bodies at rest is important to physicists, engineers and architects. A bridge, for example, is subject to many forces: gravity, wind, water currents, the weight of traffic, and so on.	
Is a tall building a body at rest? ☐ yes ☐ no	yes
Are there forces acting on it? ☐ yes ☐ no	yes
Does the designer of a building need to be concerned with the laws of motion? ☐ yes ☐ no	yes
66.	
Static means fixed. "Stationary" is a related word.	
Dynamic means active or moving. "Dynamite" is a related word.	
Statics and dynamics are two branches of physics.	
Statics deals with: ☐ bodies at rest ☐ bodies in motion	bodies at rest
Dynamics deals with: ☐ bodies at rest ☐ bodies in motion	bodies in motion

67.	
The laws of motion deal with forces acting: ☐ only on bodies at rest ☐ only on bodies in motion ☐ both of the above ☐ neither of the above	both of the above
The laws of motion are important in the study of: ☐ dynamics only ☐ statics only ☐ both of the above ☐ neither of the above	both of the above
Dynamics deals with the forces acting on (what kind of bodies?) ________________.	bodies in motion (or equivalent response)
Statics deals with the forces acting on (what kind of bodies ?) ________________.	bodies at rest (or equivalent response)
68.	
The study of forces acting on bodies at rest is called: ☐ dynamics ☐ statics	statics
The study of forces acting on bodies in motion is called: ☐ dynamics ☐ statics	dynamics
	Time completed ________________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
INERTIA	The tendency of moving objects to keep moving in a straight line without changing direction and the tendency of objects at rest to remain at rest.
FORCE	An influence on a body which tends to produce a change in movement. (Force can be measured in terms of pounds, of pull; example: 20 lbs. of pull.)
NEWTON'S FIRST LAW OF MOTION or THE LAW OF INERTIA	A body at rest tends to remain at rest and a body in motion tends to remain in motion with constant (unchanged) velocity unless acted upon by an external force.
MASS & INERTIA	The greater the mass of an object, the greater its inertia.
NEWTON'S SECOND LAW OF MOTION	A single force acting on a body will produce an acceleration such that the force is equal to the product of the body's mass times its acceleration. $F = m \times a$ In other words: lighter objects require less force to give them the same acceleration as heavy objects.
SCALAR QUANTITY	A quantity having only magnitude; this quantity can be described by measuring it on some kind of scale (such as a weighing scale or a ruler). EXAMPLES: distance, mass, and speed are scalar quantities
VECTOR QUANTITY	A quantity having magnitude and direction. EXAMPLE: force is a vector quantity.
RESULTANT FORCE	refers to the total of all the forces acting on an object at one time; EXAMPLE: if the forces on a body at rest are equal and opposite the body remains at rest the resultant force is zero.
STATICS	The study of forces acting on bodies at rest (stationary = standing still)
DYNAMICS	The study of forces acting on bodies in motion (dynamic = active, moving)

MASTERY TEST

Time started ______________

1. Inertia is the tendency of:

   a. ☐ moving objects to accelerate

   b. ☐ moving objects to resist acceleration

   c. ☐ objects at rest to accelerate

   d. ☐ objects at rest to resist acceleration

2. What does Newton's first law, the law of inertia, state?

   a. ☐ Acceleration is a change in velocity.

   b. ☐ Any change in the velocity of an object requires the application of force.

   c. ☐ Changes in velocity can occur whether force is applied or not.

   d. ☐ Inertia cannot be overcome.

3. CHECK the true statements:

   a. ☐ The less mass a body has, the greater its inertia.

   b. ☐ The less mass a body has, the smaller its inertia.

   c. ☐ The more mass a body has, the greater its inertia.

   d. ☐ The more mass a body has, the smaller its inertia.

   e. ☐ There is no connection between a body's mass and its inertia.

4. According to Newton's second law of motion, which of the following statements are true?

a. ☐ It takes more force to produce the same acceleration in a heavy object than a light one.

b. ☐ It takes more force to produce the same acceleration in a light object than a heavy one.

c. ☐ The less force you apply to an object, the greater the resulting acceleration.

d. ☐ The less force you apply to an object, the smaller the resulting acceleration.

5. MATCH the two sets of terms:

A. scalar quantity

B. vector quantity

1. _____ acceleration

2. _____ distance

3. _____ force

4. _____ mass

5. _____ velocity

6. When equal and opposite forces act on a body at rest, the resultant force is:

a. ☐ not zero

b. ☐ zero

7. If a body moves in a circular path at constant speed, what kind of force is acting on it?

a. ☐ a force at right angles to the direction of motion, away from the center

b. ☐ a force at right angles to the direction of motion, toward the center

c. ☐ a zero resultant force

d. ☐ no force at all

8. MATCH the forces described on the left with their effects on a moving body:

A. force in direction of motion	1. _____ changes both direction and speed
B. force in direction opposite to direction of motion	2. _____ changes direction but not speed
C. force at right angles to direction of motion	3. _____ decreases speed without changing direction
D. force in any other direction (not same, opposite to, or at right angles to direction to motion)	4. _____ increases speed without changing direction

9. The earth's motion is an example of:

a. ☐ only rotational motion

b. ☐ only translational motion

c. ☐ both rotational and translational motion

d. ☐ neither rotational nor translational motion

Time completed _______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-870

ED 070909

PM 431 - 63

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

TYPES OF MOTION AND REST
LEVEL: II
UNIT: 9
LESSON: 3

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

1.

ROTATIONAL MOTION AND FRICTION

In the last two lessons you learned about *translational* motion and the laws which govern it. Translational motion, you may remember, is the term physicists use in talking about objects moving from place to place.

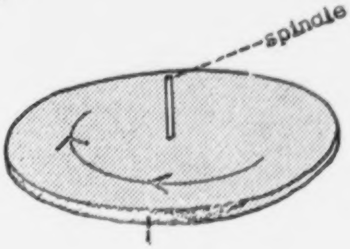
In this lesson you will learn about *rotational* motion, which refers to spinning objects.

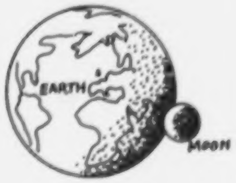
There are many similarities between the two types of motion and the terms used to describe them, so you will not have to begin all over again at the beginning.

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

2.





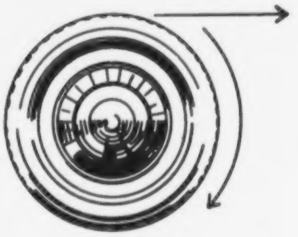
Rotational motion is often confused with the motion of an object traveling on a circular path, which is a kind of translational motion.

In rotational motion, all parts of the body turn around a center which is part of or surrounded by the body itself.

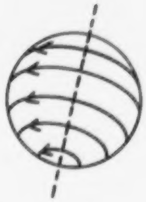
In circular motion, the entire body turns around a center which is outside the body.

What is the center around which the phonograph turntable spins? ________________	the spindle
This center is: ☐ outside the turntable ☐ part of or surrounded by the turntable	part of or surrounded by . . .
What is the center around which the moon is moving as it travels in its orbit? ________________	the earth
This center is: ☐ outside the moon ☐ part of or surrounded by the moon	outside the moon

3.	
Most astronomical bodies -- like the earth and the moon -- have two kinds of motion: translational and rotational.	
The earth, as you probably know, spins on its axis once every 24 hours (giving us day and night as we face toward or away from the sun). At the same time, the earth is traveling in its orbit around the sun, taking a full year to make each trip.	
The earth's daily turn on its axis is:	
☐ rotational motion ☐ translational motion	rotational motion
The earth's yearly trip around the sun is:	
☐ rotational motion ☐ translational motion	translational motion
4.	
If you put a spot of paint on the edge of your phonograph turntable and then switched on the record player, you would see the spot move around in a circular path. The motion of the spot is just like the motion of the earth in its orbit.	
Using this comparison, we could say that every particle making up the turntable follows a circular path -- that is, the motion of each particle is translational.	
However, when we talk about rotational motion, we consider the spinning body as a whole, rather than the individual particles that make up the body.	
NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

5.	
	
A wheel on a car, like the earth, goes through two different kinds of motion.	
The turning of the wheel around the axle is:	
☐ rotational motion ☐ translational motion	rotational motion
What would you call the motion of the wheel rolling along the ground? ______________	translational (motion)
6.	
Next to each example, WRITE T for translational motion or R for rotational motion:	
_____ car traveling along a road	T
_____ door turning on its hinges	R
_____ earth spinning on its axis	R
_____ earth moving around the sun	T
_____ car wheels going around axle	R

7.



You have probably seen drawings like this one before. They are used to represent the rotational motion of the earth. The dotted lines extending from the "poles" indicate the earth's axis.

Of course, there is nothing actually sticking out of the earth at these points.

The earth's axis is:

- ☐ an imaginary line
- ☐ a real object which can be felt, seen, and touched

an imaginary line

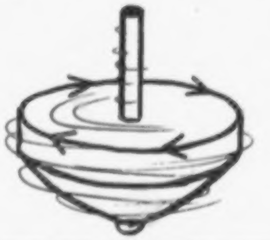
8.

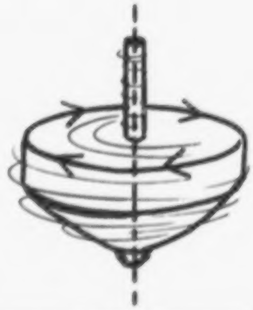
The earth's axis is a "line" that we imagine running straight through the earth from pole to pole. The rotation of the earth is around this axis.

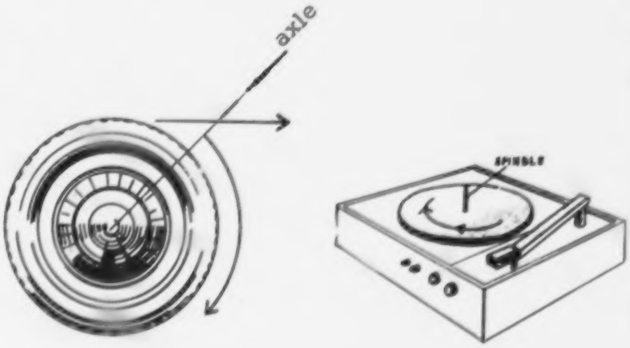
It helps to think of the axis as the part that stands still while every other part of the earth turns around it.

The earth's axis is an example of the axis of rotation found (or imagined!) in every body with rotational motion.

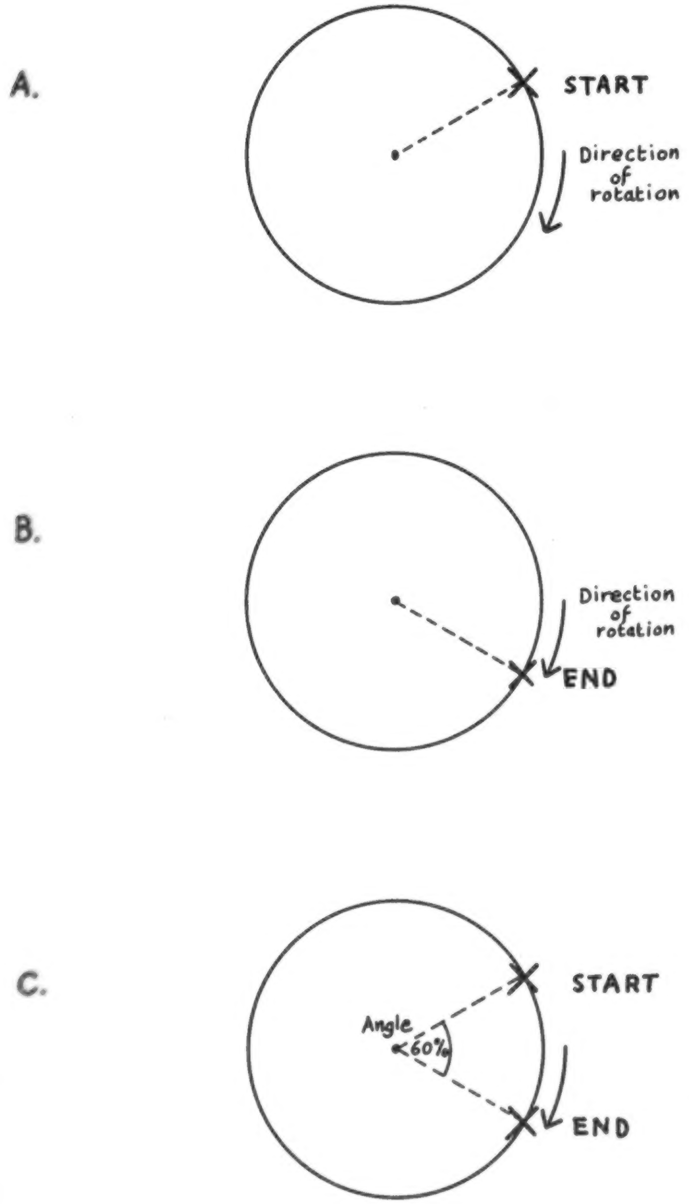
DRAW a dotted line through the spinning top shown below to show its axis of rotation.





9.  The axis of rotation is not always an imaginary line. Some rotating bodies spin on a real object. What is the axis of rotation of a car wheel? ______________ What is the axis of rotation of a turntable? ______________	the axle the spindle
10. The axis of rotation is characteristic of: ☐ only rotational motion ☐ only translational motion ☐ all motion	only rotational motion
11. The axis of rotation: ☐ is always imaginary ☐ is always real ☐ may be real or imaginary	may be real or imaginary

PANEL 1


A.
START
Direction of rotation
B.
Direction of rotation
END
C.
START
Angle
<60%
END

12. A basic measure of translational motion is distance -- how far an object moves from its starting point. In rotational motion, does the body actually move from place to place? ☐ yes ☐ no Would you expect distance from the starting point to be measured in the same way for rotational motion as for translational motion? ☐ yes ☐ no	no no
13. REFER TO PANEL 1 The diagrams on the panel illustrate how we measure "distance" in rotational motion. In A, we have chosen a point along the outer edge of a turntable to mark the starting position. Any point along the edge would do as well. Now we start the phonograph and stop it quickly. B shows the new position of the turntable. C combines diagrams A and B. In addition, the angle through which the turntable has moved is shown -- in this case, 60°. The rotational measure corresponding to distance is called the angle of rotation. What was the angle of rotation in the example given on Panel 1? _____	60°

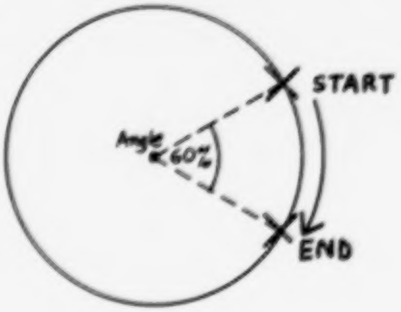
14.

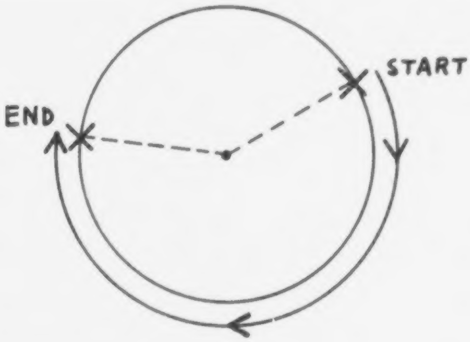
In translational motion, we distinguish between distance and displacement, and between speed and velocity, because both displacement and velocity include direction.

For our purposes, direction has no meaning in rotational motion. For this reason, we will make no distinction between distance and displacement, or between speed and velocity when we discuss rotational motion.

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

15.	
	
The angle of rotation -- the angle through which a body rotates -- is called the angular displacement of the body.	
In translational motion, displacement refers to:	
☐ a body's new position relative to its old position	a body's new position . . .
☐ a body's resistance to acceleration	
☐ the change in a body's velocity in a given time	
In rotational motion, angular displacement refers to:	
☐ a body's new position relative to its old position	a body's new position . . .
☐ a body's resistance to acceleration	
☐ the change in a body's velocity in a given time	
In translational motion, displacement is described in terms of direction, and distance. In rotational motion, displacement is described in terms of:	
☐ an angle of rotation ☐ direction ☐ distance	an angle of rotation

16.  A full circle equals 360°. A half-circle equals 180°. What is the angular displacement shown in this drawing? ☐ less than 180° ☐ 180° ☐ more than 180° but less than 360° ☐ 360°	more than 180° but less than 360°
17. If a body makes one complete turn, its angular displacement is 360°. If it makes two complete turns, its angular displacement is (360° for each turn) _____.	720°
18. If a body spins very fast, it is inconvenient to talk about angular displacement in degrees. Instead, we talk about the number of revolutions, meaning the number of complete turns, the body makes. Suppose we measure an angular displacement of 900°. Remember that a full turn (circle) is 360° and a half-circle is 180°. How many turns has the body made? _____ The angular displacement of 900° can be stated as (how many?) _____ revolutions.	2 1/2 2 1/2

19. Angular displacement can be measured in: ☐ degrees ☐ revolutions	degrees revolutions
20. In translational motion, velocity is a body's displacement per second, minute, or hour. Similarly, angular velocity is a body's angular displacement per unit of time. Which of the following describe angular velocity? ☐ 5 revolutions per minute ☐ 10 feet to the east per second ☐ 20 ☐ 30 revolutions ☐ north at 35 miles per hour ☐ 60° per hour	5 revolutions per minute 60° per hour
21. If you have ever heard the terms "45 rpm record" and "33 1/3 rpm record," you are already familiar with an everyday example of angular velocity: "rpm" stands for revolutions per minute When you play a record marked "33 1/3 rpm," the angular velocity of your record player should be (what?) ______________ If the record takes 3 minutes to play, how many complete turns will the turns will the turntable make? _____	33 1/3 rpm (or 33 1/3 revolutions per minute) 100 revolutions

22. What do each of the following describe? WRITE V for velocity (translational), AV for angular velocity, D for displacement (translational), or AD for angular displacement.	
_____ 2 miles per second to the northwest	V
_____ 39°	AD
_____ 50 miles south	D
_____ 78 revolutions per minute	AV
23. In translational motion, as you probably remember, acceleration is any change in velocity. Angular acceleration has much the same meaning. You can tell, then, that angular acceleration means:	
☐ only a decrease in angular velocity ☐ only an increase in angular velocity ☐ an increase or a decrease in angular velocity	an increase or a decrease . . .
24. "In one second, the record player went from 45 rpm to 33 1/3 rpm." This statement describes:	
☐ angular acceleration ☐ angular displacement ☐ angular velocity	angular acceleration
"The earth makes a complete turn around its axis every 24 hours." This statement describes:	
☐ angular acceleration ☐ angular displacement ☐ angular velocity	angular velocity

25.

MATCH the terms listed on the left with their definitions.

A. angular acceleration

B. angular displacement

C. angular velocity

D. axis of rotation

1. _____	how fast a rotating object turns	1. C
2. _____	how much and how quickly the angular velocity of a rotating body changes	2. A
3. _____	angle through which a rotating body turns	3. B
4. _____	imaginary (or real) line around which a rotating object turns	4. D

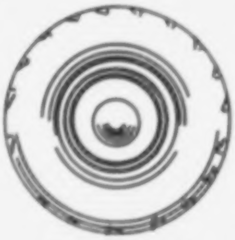
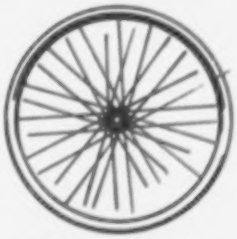
26.

Inertia is the tendency of bodies to resist acceleration. Rotating bodies, like other bodies, have inertia. In discussing rotational motion, we use the term rotational inertia.

Rotational inertia implies that (CHECK one or more):

☐ a body at rest will not begin to rotate by itself	a body at rest will not begin . . .
☐ a body will start to rotate by itself	
☐ a rotating body will continue to turn at constant angular velocity unless something stops it	a rotating body will continue . . .
☐ a rotating body will stop turning by itself	(It is true that rotating bodies do gradually slow down and stop, apparently without any force being applied. However, an "unseen" force, friction, is at work. You will learn about friction later in this lesson. Meanwhile, we will talk about rotational motion as if friction did not affect it.)

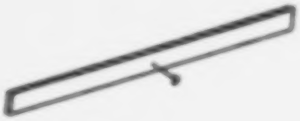
27. Rotational inertia is: ☐ how fast a rotating body turns ☐ the angle through which a rotating body turns ☐ the resistance of a rotating body to changes in angular velocity	the resistance of a rotating . . .
28. REVIEW FRAME In translational motion, how are inertia and mass related? ☐ The greater the mass of a body, the greater its inertia. ☐ The greater the mass of a body, the less its inertia. ☐ They are not related at all.	. . . the greater its inertia.

29.  Truck Wheel  Bicycle Wheel	
Which is easier to turn on its axle? ☐ a bicycle wheel ☐ a truck wheel	a bicycle wheel
Which is heavier? ☐ a bicycle wheel ☐ a truck wheel	a truck wheel
What is the relationship between rotational inertia and mass? ☐ The greater the mass of a body, the greater its rotational inertia. ☐ The greater the mass of a body, the less its rotational inertia. ☐ They are not related at all.	. . . the greater its rotational . . .

30.

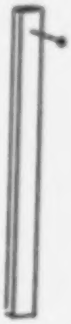
The rotational inertia of a body depends not only on its mass, but on the position of its axis of rotation as well.

For example, suppose you drive a nail loosely through the center of a stick into a board, then push one end of the stick to turn it:



the stick will turn easily.

Now, if you take out the nail at the center and nail it, instead, at one end:



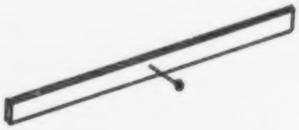
you will find the stick is harder to turn.

What has changed?

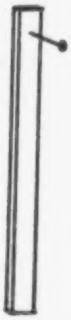
☐ the mass of the body
☐ the position of the axis of rotation

the position of the axis . . .

31.



EASY TO TURN



HARD TO TURN

A stick will rotate more easily if the axis of rotation:

☐ is close to the center
☐ is near one end

is close to the center

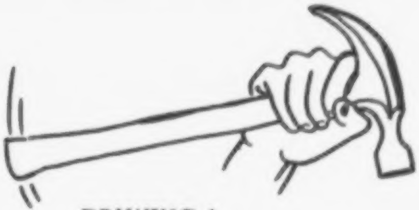
32.

In a stick, the weight (mass) is evenly distributed throughout the body; that is, each part of it weighs the same as any other part.

In such a case, we can state simply that the closer the axis of rotation is to the center, the less rotational inertia the body will have (the easier it will be to turn).

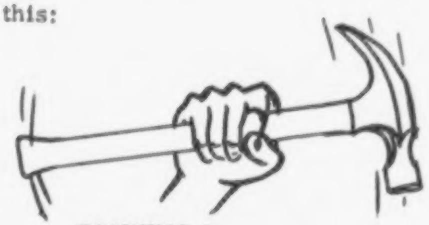
However, if a body's weight is unevenly distributed, the ideal location for the axis of rotation is usually not the center.

For example, it is easier to rotate a hammer like this:



DRAWING A

than like this:



DRAWING B

Physicists use a formula which takes into account the distribution of mass in a body to determine the rotational inertia for different positions of the axis of rotation. This combined measure of mass and location of the axis of rotation is called the moment of inertia.

Will the moment of inertia be the same for Drawing A and Drawing B?

☐ yes
☐ no

no

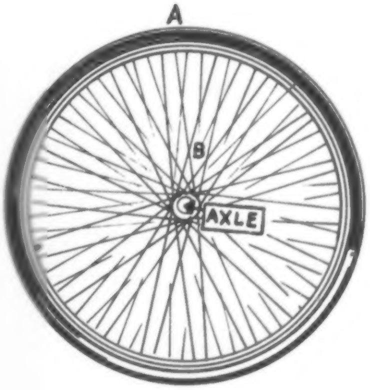
33. A body's inertia, in translational motion, depends only on its mass. What determines rotational inertia? ☐ only a body's mass ☐ only the position on a body of its axis of rotation ☐ both mass and the position of the axis of rotation	both mass and the position . . .
34. Which of the following determine(s) the rotational inertia of a body? ☐ its angular velocity ☐ its moment of inertia ☐ its position in space ☐ its mass ☐ the position of its axis of rotation	its mass the position of its axis of . . .

35.

Force, in translational motion, is simply the push or pull on a body which changes its velocity. A force of the same magnitude and direction always has the same effect on the velocity of a particular body.

In rotational motion, the effect of a force depends on where it is applied.

For example, a force at point A on the bicycle wheel below will set the wheel spinning faster than the same force at point B.



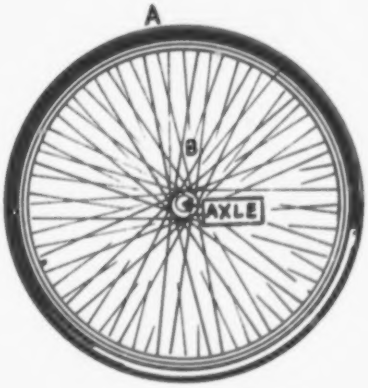
In other words, a given force applied to point A gives the wheel:

☐ greater angular acceleration than the same force applied to point B

☐ less angular acceleration than the same force applied to point B

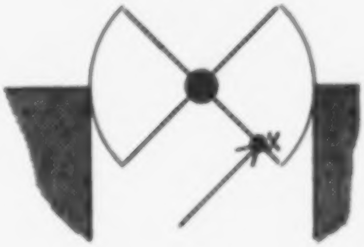
greater angular acceleration . . .

36.



A force at A produces greater acceleration than the same force at B.	
Which point is closer to the axis of rotation? ☐ A ☐ B	B
The effect of a force on a rotating body is greater when it is applied: ☐ closer to the axis of rotation ☐ farther from the axis of rotation	farther from the axis of rotation

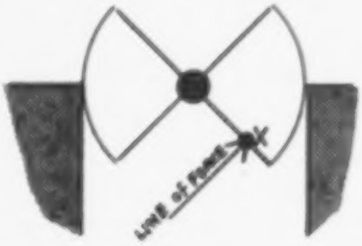
37.



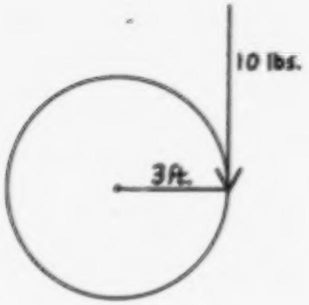
The drawing shows a revolving door. It is pushed at the spot marked X. The direction of the push is shown by the arrow.

A line showing the direction of a force is called a line of force.

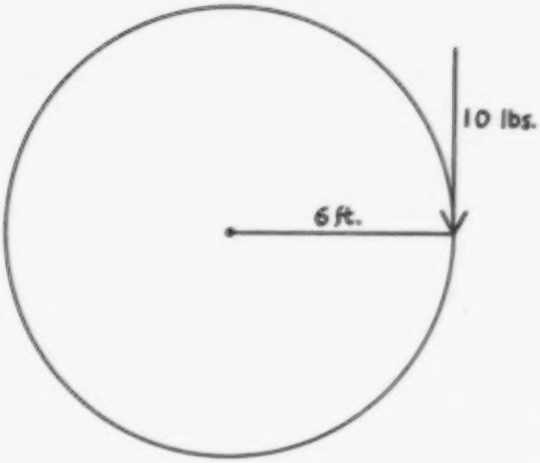
LABEL the line of force in the drawing.



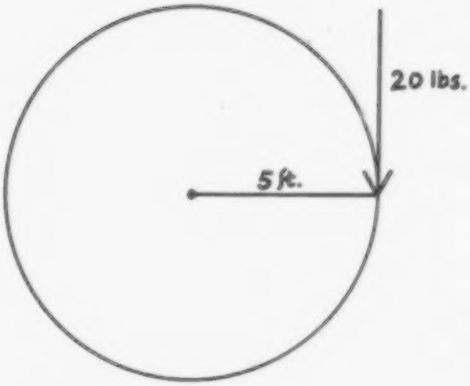
PANEL 2



A.

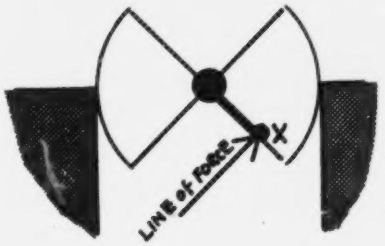


B.



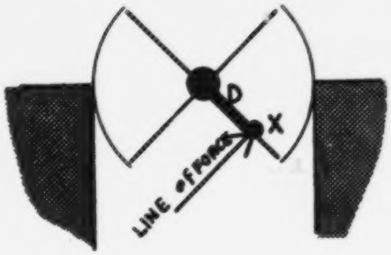
C.

38.



The distance from the line of force to the axis of rotation determines the effect of the force.

FIND a line in the drawing which represents this distance. LABEL it D.



Suppose the point where the door is pushed was closer to the axis of rotation. What would happen?

☐ The door would turn faster.
☐ The door would turn slower.

The door would turn slower.

39.

REFER TO PANEL 2

The effect of a force applied to a rotating body is the product of the force times the distance from the line of force to the axis of rotation.

In Drawing A, for example, the turning effect of the force is 10 (lbs.) x 3 (ft.) = 30 (foot-pounds)

FIGURE the effect of the force in Drawing B:

_____(lbs.) x _____(feet) = _____ (foot-pounds)

6 x 10 = 60

40. The effect of a force on a rotating body is determined by 1) the amount of the force, and 2) the distance from the line of force to the axis of rotation. How is the effect of the force calculated? ☐ by adding 1 and 2 ☐ by dividing 1 by 2 ☐ by miltiplying 1 by 2 ☐ by subtracting 1 from 2	by multiplying 1 by 2
41. The effect of a force on a rotating body is the product of two numbers. What are the two numbers multiplied? ☐ the amount of the force ☐ the distance from the line of force to the axis of rotation ☐ the mass of the body ☐ the position of the axis of rotation	the amount of the force the distance from the line . . .
42. REFER TO PANEL 2 The effect of a force on a rotating body is called torque. CALCULATE the torque for Drawing C.	20 (lbs.) x 5 (ft.) = 100 (lb - ft)

43. Torque is a measure of: ☐ the amount of a force applied to a rotating body ☐ the effect on angular velocity of a force applied to a rotating body ☐ the resistance of a rotating body to changes in angular velocity	the effect on angular velocity . . .
44. MATCH the terms used in translational motion with the corresponding terms used in rotational motion. A. acceleration B. displacement C. force D. inertia E. velocity 1. _____ angular acceleration 2. _____ angular displacement 3. _____ angular velocity 4. _____ rotational inertia 5. _____ torque	1. A 2. B 3. E 4. D 5. C

45.

As applied to translational motion, Newton's first law of motion, the law of inertia, states:

> "A body at rest tends to remain at rest and a body in motion tends to remain in motion at constant velocity unless acted upon by an external force."

By changing the underlined words and phrases we can make this law apply to rotational motion. For example, we can replace "body in motion" by rotating body and "remain in motion" by continue to rotate.

What should replace the word "velocity"?

- ☐ angular acceleration
- ☐ angular velocity
- ☐ rotational inertia
- ☐ torque

What should replace the word "force"?

- ☐ angular acceleration
- ☐ angular velocity
- ☐ rotational inertia
- ☐ torque

angular velocity

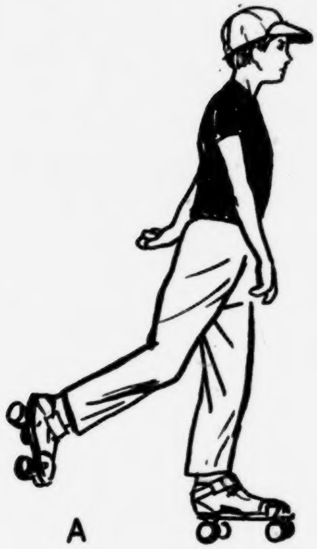
torque

46.	
$$F = m \times a$$	
In translational motion, this mathematical statement of Newton's second law of motion tells us that a force, F, applied to a body of mass, m, will produce an acceleration, a. The force will equal the mass times the acceleration.	
It seems reasonable to assume that there is a mathematical statement of Newton's second law of motion for rotational motion as well; and there is.	
From what you have already learned, you know that force in translational motion corresponds, in rotational motion, to:	
☐ angular acceleration ☐ axis of rotation ☐ torque	torque
In rotational motion, what corresponds to acceleration?	
☐ angular acceleration ☐ axis of rotation ☐ torque	angular acceleration

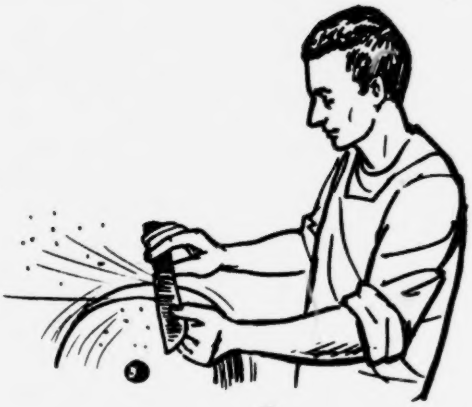
47. F = m x a T = ? x ang. a. In rotational motion, the corresponding mathematical statement of Newton's second law of motion has torque (T) instead of force, and angular acceleration (ang. a.) instead of acceleration. Let us see what should replace mass. In translational motion, mass represents a body's resistance to acceleration -- its inertia. What is a rotating body's resistance to acceleration called? ☐ axis of rotation ☐ rotational inertia ☐ torque	rotational inertia
In rotational motion, does the resistance of a body to acceleration depend only on its mass? ☐ yes ☐ no	no
48. What two factors determine the rotational inertia of a body? ☐ its angular velocity ☐ its mass ☐ the position of its axis of rotation	its mass the position of its axis of . . .
In rotational motion, rotational inertia (r.i.) takes the place of mass in translational motion. In words, a corresponding mathematical statement for F = m x a is: "A torque T applied on a body with rotational inertia r.i. will produce an angular acceleration ang.a. The torque is equal to the rotational inertia times the angular acceleration. Using the underlined abbreviations in the statement above, write the mathematical formula for Newton's law of inertia as it applies to rotational motion. ________________________	T = r.i. x ang.a.

49. T = r.i. x ang. a. (torque) (rotational inertia) (angular acceleration) Suppose you want to calculate what the angular acceleration of a body will be in a particular situation. You can work out the angular acceleration if you know the rotational inertia of the body and the torque. What information will you need to figure rotational inertia and torque? ☐ amount of force ☐ body's mass ☐ body's velocity ☐ distance from line of force to axis of rotation ☐ location on body of axis of rotation	amount of force body's mass distance from line of force . . . location on body of axis . . .
50. GIVE the mathematical statements for Newton's second law of motion, for translational motion and for rotational motion, using the following symbols: a for acceleration ang. a. for angular acceleration F for force m for mass r. i. for rotational inertia T for torque Translational motion: ________________ Rotational motion: ________________	F = m x a T = r. i. x ang. a.

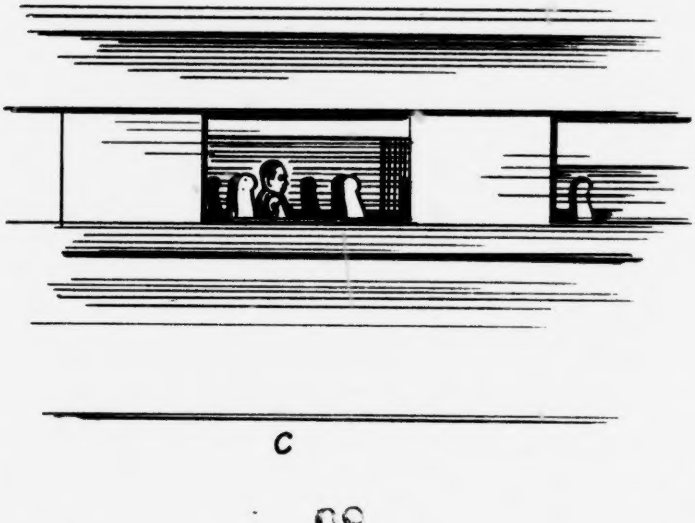
PANEL 3



A



B



C

51. (a) Bodies at rest tend to remain at rest and (b) bodies in motion tend to remain in motion at constant velocity (rotating bodies tend to continue to rotate at constant angular velocity). Our experience does not contradict the first part of this statement (a) -- we know that objects don't just start moving for no reason. But the second part (b) is another matter. We all know that objects in motion do slow down and come to a stop, seemingly by themselves. Now you are ready to understand why this happens. In the remainder of this lesson, you will learn what force affects all motion. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
52. REFER TO PANEL 3 (Page 32) Drawing A shows a boy roller skating. Which is moving?	
☐ his skates ☐ the sidewalk	his skates
Drawing B shows a man holding a knife against a grinding wheel to sharpen the knife. Which is moving?	
☐ the grinding wheel ☐ the knife	the grinding wheel

53.	
REFER TO PANEL 3	
Looking at Drawing A, we say that the sidewalk stands still and the skates move.	
A physicist would say that the skates and the sidewalk are in motion relative to each other.	
"In motion relative to each other" simply means that, no matter which body is moving, they are not both moving in the same direction and at the same speed. In other words, it makes no difference which one is moving, as long as their velocities are different.	
Is the knife in Drawing B moving at the same speed and in the same direction as the grinding wheel?	
☐ yes ☐ no	no
Are the two objects in Drawing B (the knife and the grinding wheel) in motion relative to each other?	
☐ yes ☐ no	yes
54.	
REFER TO PANEL 3	
Drawing C shows a man sitting in a moving train.	
Is the train in motion relative to the tracks?	
☐ yes ☐ no	yes
Is the man in motion relative to the train? (HINT: As long as he sits there, he will go wherever the train goes, no faster and no slower.)	
☐ yes ☐ no	no

55.	
Two objects moving in the same direction at the same speed:	
☐ are in motion relative to each other	
☐ are not in motion relative to each other	are not in motion relative . . .
The phrase "in motion relative to each other" tells us:	
☐ which of two objects is moving	
☐ whether both objects are moving or only one is	
☐ only whether two objects have different velocities	only whether two objects . . .
56.	
Friction is the force which slows down and eventually stops moving or rotating bodies.	
Friction is the resistance to relative motion (motion relative to each other) of two bodies in contact with each other.	
When you roll a ball along a floor, it will finally slow down and stop.	
What causes it to stop?	
☐ the ball's resistance to acceleration	
☐ the floor's resistance to acceleration	
☐ the resistance of the ball and the floor to relative motion	the resistance of the ball . . .
What one word describes this resistance? ________________	friction

57. Friction is the resistance to relative motion of two bodies in contact with each other. An airplane is slowed down by friction with the air. In this situation, then, you can say that the air is: ☐ a "body" in relative motion with the airplane ☐ a "body" in contact with the airplane	a "body" in relative motion . . a "body" in contact with the . . .
58. What is the term for the force which prevents motion from continuing indefinitely? ☐ friction ☐ inertia ☐ torque	friction
59. What produces friction? ☐ the resistance of a body to changes in velocity ☐ the resistance to relative motion of bodies in contact with each other	. . . to relative motion of . . .

60. Friction is: ☐ any force which prevents motion from continuing indefinitely ☐ the effect of a force applied to a rotating body ☐ the resistance of a rotating body to changes in angular velocity ☐ the resistance to relative motion of two bodies in contact with each other	. . . to relative motion . . .
61. Friction affects only the speed of moving or rotating objects. Going back to what you learned in an earlier lesson, what kind of force slows down an object without changing its direction? ☐ a force at right angles to the body's direction of motion ☐ a force in the same direction as the body's direction of motion ☐ a force in the direction opposite to the body's direction of motion	. . . in the direction opposite . . .
62. Friction exerts: ☐ a force in the direction of motion ☐ a force in the direction opposite to the direction of motion ☐ no force	. . . direction opposite to . . .

63. Physicists distinguish between two kinds of friction: A. the friction which prevents bodies at rest from being set in motion B. the friction which slows down moving objects One kind is called static friction. In an earlier lesson, you learned about a branch of physics called statics, which deals with the forces acting on bodies at rest. From this fact, you can tell that static friction is the kind described in: ☐ A, above ☐ B, above	A, above
64. "Kinetic" is a term used in physics to refer to motion. One kind of friction is called kinetic friction. Kinetic friction is: ☐ the friction which prevents bodies at rest from being set in motion ☐ the friction which slows down bodies in motion	. . . slows down bodies . . .

65.	
You are rearranging the furniture in your room. You want to slide a heavy dresser across the floor. You push, and nothing happens. You push a little harder -- still it won't budge. Finally, you give it all you have, and it starts to move. Now you can slide it over the rest of the way with much less effort.	
The force that works against you in getting the dresser to start moving is:	
☐ kinetic friction	
☐ static friction	static friction
The force you work against to keep it moving is:	
☐ kinetic friction	kinetic friction
☐ static friction	
Which force do you have to work harder to overcome? ________________ friction	static
Which one must be a greater force? ________________ friction	static
66.	
The harder you push on a stationary object, the more it seems to resist, until you reach a point where your push is strong enough to overcome the resistance.	
Once you get the object moving, a steady push keeps it going.	
Physicists say that something has a maximum value if it keeps getting larger up to a certain point then decreases.	
Which has a maximum value?	
☐ kinetic friction	
☐ static friction	static friction
Which is larger in any particular situation?	
☐ kinetic friction	
☐ static friction	static friction

67.

MATCH the terms on the left with the statements on the right.

A. kinetic friction	1. ______ has a maximum value	1. B
B. static friction	2. ______ prevents bodies from being set in motion	2. B
	3. ______ slows down moving bodies	3. A

68.

Which is larger?

☐ kinetic friction
☐ static friction

static friction

Time completed ______________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
AXIS OF ROTATION	An axis is a real or imaginary line around which a rotating object moves. The real or imaginary axis is stationary while the rotating object turns around it. EXAMPLE: The imaginary line extending between the north and south poles of the earth indicate the earth's axis/ the earth rotates around this axis.
ANGULAR DISPLACEMENT	A rotating body's new position relative to its old position is measured by the angle through which the rotating body turns, the angular displacement is measured in degrees. (example: 60°)
REVOLUTIONS	refers to the number of complete turns a rotating body makes; this measure is used instead of angular displacement when a body is spinning very fast.
VELOCITY	expresses how fast a rotating object turns (that is, the body's angular displacement per unit of time); revolutions per minute (rpm's) is a familiar example of angular velocity.
ANGULAR ACCELERATION	refers to how much and how quickly the angular velocity of a rotating body changes.
DISTRIBUTION OF MASS	refers to the way the weight (mass) is spread throughout a body. For example: in a stick the mass is evenly distributed; in a hammer the mass is unevenly distributed. If a body's weight is unevenly distributed, the axis of rotation is usually not at its center.
MOMENT OF INERTIA	The measure which determines the rotational inertia for different positions of the axis of rotation.
ROTATIONAL INERTIA	refers to a body's resistance to acceleration; the mass and the position of the axis of rotation determine how much force is needed to overcome the rotational inertia of a body.
LINE OF FORCE	A line showing the direction of force.
TORQUE	The effect of a force on a rotating body: the amount of force (measured in pounds) times the distance from the line of force to the axis of rotation (measured in feet) equals the torque (labeled as pounds-foot).

SUMMARY SHEET

COMPARISON OF TRANSLATIONAL MOTION AND ROTATIONAL MOTION

TRANSLATIONAL	ROTATIONAL
acceleration	angular acceleration
displacement	angular displacement
force	torque
inertia	rotational inertia

NEWTON'S FIRST LAW

A body at rest tends to remain at rest and a body in motion tends to remain in motion at constant velocity unless acted upon by an external force.

A body at rest tends to remain at rest and a rotating body tends to continue to rotate unless acted upon by an external force.

NEWTON'S SECOND LAW

Force = mass x acceleration

$$F = m \times a$$

Torque = rotational inertia x angular acceleration

$$T = \text{r.i.} \times \text{ang. a}$$

A torque T applied on a body with rotational inertia r.i. will produce an angular acceleration ang.a The torque is equal to the rotational inertia times the angular acceleration.

WORD	DEFINITION
OBJECTS IN MOTION RELATIVE TO EACH OTHER	describes whether two objects have different velocities.
FRICTION	The resistance to relative motion of two bodies in contact (touching) with one another; Friction exerts a force in the direction opposite to the direction of motion; friction affects only the speed of moving or rotating objects.
STATIC FRICTION	refers to friction which prevents bodies at rest from being set in motion; static friction has a maximum value meaning that a stationary object will resist being moved until a point is reached where the force is strong enough to overcome the resistance. This point is the maximum value of the static friction.
KINETIC FRICTION	The friction which slows down bodies in motion. Static friction is harder to overcome than kinetic friction.

MASTERY TEST

Time started ______________

1. Which of the following is/are examples of rotational motion?

   a. ☐ movement of a record on a record player
   b. ☐ satellite traveling around the earth
   c. ☐ train going along a track
   d. ☐ turning of a bicycle wheel

2. Angular displacement is expressed:

   a. ☐ only in degrees
   b. ☐ only in revolutions
   c. ☐ both in degrees and in revolutions
   d. ☐ neither

3. MATCH the terms with their definitions.

   A. angular velocity
   B. axis of rotation
   C. rotational inertia
   D. torque

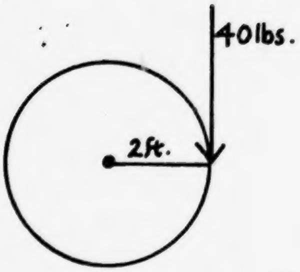
   1. _____ effect of a force applied to a rotating body
   2. _____ how fast a rotating body turns
   3. _____ line around which a rotating body turns
   4. _____ resistance of a rotating body to changes in angular velocity

4. The rotational inertia of a body depends on:

   a. ☐ its angular velocity
   b. ☐ its mass
   c. ☐ its position in space
   d. ☐ its torque
   e. ☐ the position of its axis of rotation

NOTE: Skip one(1) page to find page 46 and continue with question 5.

5.



In the example shown above, the torque is _____ pound-feet.

6. "A body at rest tends to remain at rest, and a body in motion tends to remain in motion at constant velocity, unless acted upon by an external force."

This statement of Newton's second law of motion, the law of inertia:

a. ☐ applies to rotational motion in the form shown

b. ☐ applies to translational motion in the form shown

c. ☐ could be applied to rotational motion by changing a few words and phrases

d. ☐ could be applied to translational motion by changing a few words and phrases

e. ☐ has no application to rotational motion

f. ☐ has no application to translational motion

NOTE: Continue with question 7 on next page.

7. GIVE the mathematical statements for Newton's second law of motion, for translational motion and for rotational motion, using the following symbols:

a for acceleration

ang. a. for angular acceleration

F for force

m for mass

r. i. for rotational inertia

T for torque

Translational motion: ________________

Rotational motion: ________________

8. Friction is a force (CHECK one or more):

a. ☐ acting at right angles to the direction of motion

b. ☐ acting in the direction of motion

c. ☐ acting in the direction opposite to the direction of motion

d. ☐ applied to a rotating body

e. ☐ which prevents motion from continuing indefinitely

NOTE: Continue with question 9 on next page.

9. MATCH the terms with the statements on the right:

A. kinetic friction	1. _____ has a maximum value
B. static friction	2. _____ is the larger of the two kinds of friction
	3. _____ prevents bodies from being set in motion
	4. _____ slows down moving bodies

Time completed _______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-871

PM 431 64

ED 070909

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

ELECTRICITY AND MAGNETISM
LEVEL: II
UNIT: 9
LESSON: 4

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

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MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

1.

PREVIEW

In the next two lesson units you will learn about three different types of forces which are found in the world.

NO RESPONSE REQUIRED

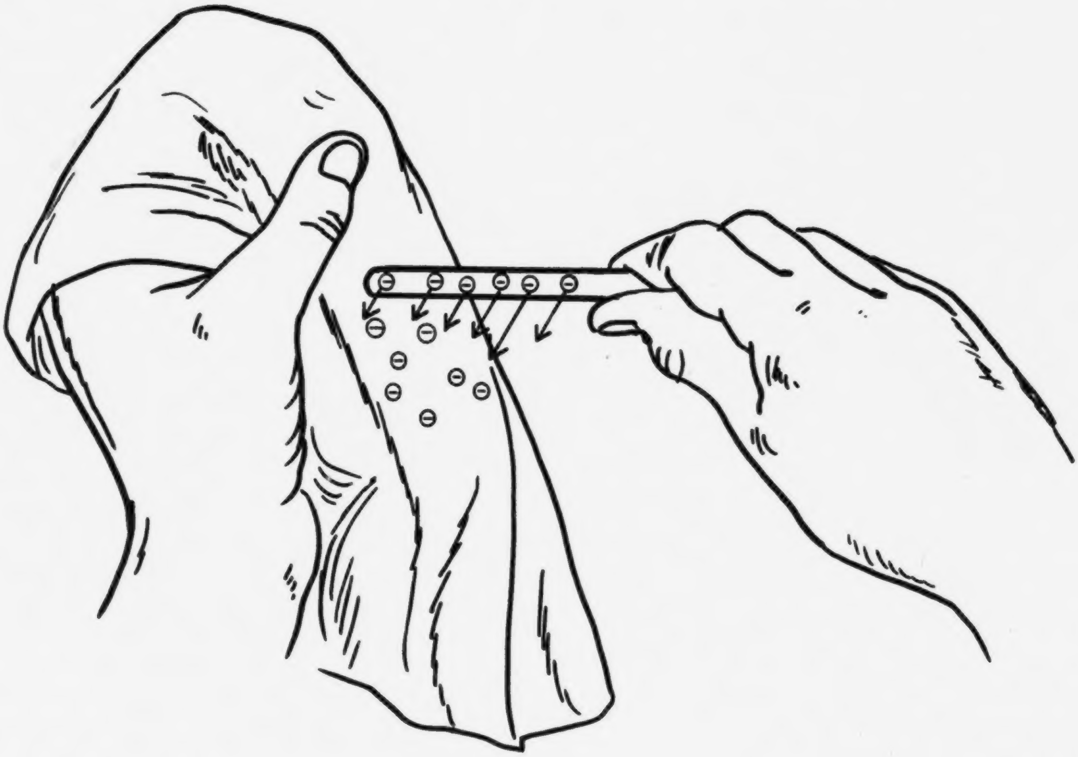
GO ON TO NEXT FRAME

2. REVIEW An atom is made up of:	
☐ electrons	electrons
☐ protons	protons
☐ neutrons	neutrons

3.	
An electron is a particle with:	
☐ a negative charge	a negative charge
☐ a positive charge	
☐ no charge	
A proton is a particle with:	
☐ a negative charge	
☐ a positive charge	a positive charge
☐ no charge	
A neutron is a particle with:	
☐ a negative charge	
☐ a positive charge	
☐ no charge	no charge

4.	
The number of electrons and the number of protons in an atom are:	
☐ different	
☐ the same	the same
Consequently, the atom as a whole has:	
☐ a negative charge	
☐ a positive charge	
☐ no charge	no charge

PANEL 1



5.

LOOK at Panel 1.

The picture in Panel 1 shows a glass rod and a piece of silk being rubbed together. When the rod and silk are rubbed together, electrons jump from the rod to the silk.

As a result, the glass rod is left with:

- ☐ fewer electrons than protons
- ☐ more electrons than protons
- ☐ the same number of electrons as protons

And the silk has:

- ☐ fewer electrons than protons
- ☐ more electrons than protons
- ☐ the same number of electrons as protons

fewer electrons than . . .

more electrons than . . .

6.

When a body of matter, such as a glass rod or a piece of silk, has too few or too many electrons, it is said to have an electric charge, just as a single atom acquires a charge when electrons are added to it, or subtracted from it. (You might recall that the atom is then called an ion.)

Because electrons are particles with negative charges, a body that has more electrons than protons has an overall negative charge. Conversely, a body that has fewer electrons than protons has an overall positive charge.

LOOK at Panel 1.

As the result of rubbing, the glass rod:

☐ acquires a negative charge

☐ acquires a positive charge

☐ does not acquire any charge

And the piece of silk:

☐ acquires a negative charge

☐ acquires a positive charge

☐ does not acquire any charge

acquires a positive charge

acquires a negative charge

7.	
A body with a positive charge is one that has:	
☐ a deficiency of electrons	a deficiency of electrons
☐ an excess of electrons	
A body with a negative charge is one that has:	
☐ a deficiency of electrons	
☐ an excess of electrons	an excess of electrons

8.

Before they are rubbed together, the glass rod and the piece of silk:

☐ are electrically charged bodies

☐ are not electrically charged bodies

are not electrically . . .

9.

In the previous frames we have reviewed material on electrical charges which you have already learned.

In the following frames we will learn more about the properties of electrons, the units of negative charge, and the effects they produce in different types of substances. This material will form the basis for later parts of this lesson unit.

NO RESPONSE REQUIRED

GO ON TO NEXT FRAME

10. You have learned that, in an atom, electrons circle around the nucleus in paths called orbits. When electrons circle around the nucleus, they: ☐ are moving ☐ are not moving	are moving

11.

The electrons in the outermost orbit of an atom are least tightly bound to the nucleus.

As a result, these electrons:

- ☐ always stay in orbit around the nucleus
- ☐ can escape from orbit around the nucleus

can escape from . . .

12.

All electrons in an atom move in orbits around the nucleus of the atom.

The electrons which move in the outermost orbit of an atom are those which are:

☐ least tightly bound to the nucleus

☐ most tightly bound to the nucleus

As a result, the electrons in the outermost orbit of an atom:

☐ always stay in their orbits around the nucleus

☐ can escape from their orbits around the nucleus

least tightly bound . . .

can escape from . . .

13.	
Electrons in the outermost orbit of an atom can escape from their orbits. These electrons are known as free electrons.	
When an electron escapes from its orbit around the nucleus of one atom, it can go into orbit around the nucleus of a neighboring atom. We say that the electron jumps from one atom to another atom.	
An electron jumps from one atom to another. This:	
☐ is a type of electron movement	is a type of electron . . .
☐ is not a type of electron movement	
Can free electrons jump from one atom to another?	
☐ yes	yes
☐ no	

14.

Free electrons can jump from atom to atom. This jumping is a type of electron movement.

Is the circling of electrons in their orbits a type of electron movement?

☐ yes

☐ no

Any movement of electrons in a body of matter is an electric current. Any electron movement, whether in a straight line or in a circle, is an electric current.

The jumping of free electrons from atom to atom is a type of electric current.

The circling of electrons in orbits around a nucleus:

☐ is a type of electric current

☐ is not a type of electric current

yes

is a type of electric . . .

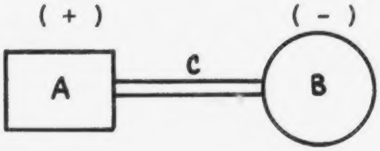
15.

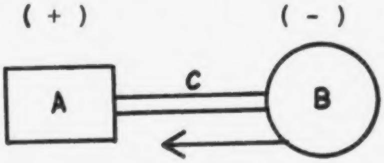
The circling of electrons in orbit and the jumping of free electrons from one atom to another are both types of electric currents.

There is another type of electron movement, or electric current. This is the movement of electrons from a charged body having an excess of electrons towards a charged body having a deficiency of electrons. In this way the charge on both bodies is neutralized.

In the diagram below, A, is a positively charged body, B, is a negatively charged body, and C is a substance, (like a copper wire), through which electrons can move.

DRAW an arrow to show the direction in which electrons will flow from one body to another.





16.	
When two oppositely charged bodies come into contact, either directly or by means of a conducting substance like a copper wire, electrons flow:	
☐ from the negatively charged body to the positively charged body	from the negatively . . .
☐ from the positively charged body to the the negatively charged body	
The flow of electrons between oppositely charged bodies:	
☐ is a type of electric current	is a type of electric . . .
☐ is not a type of electric current	
A conductor or conducting substance is a material through which electrons:	
☐ can move	can move
☐ cannot move	

17.

Which of the following are electric currents?

☐ circling of electrons in orbits around the nucleus of an atom	circling of electrons . . .
☐ flow of electrons, directly or through a conductor, from a negatively to a positively charged body	flow of electrons . . .
☐ jumping of free electrons from atom to atom	jumping of free electrons . .

Electric currents consist of:

☐ moving electrons	moving electrons
☐ non-moving electrons	

18.	
The various movements of electrons are all electric currents.	
In most types of matter, the electron movements occur in many different directions. In such substances the electric currents:	
☐ are all arranged in one direction	
☐ are arranged in many different directions	are arranged in many . . .
In the case of some substances, most of the electron movements occur in one direction. For example, the electrons in a negatively charged body tend to flow towards a positively charged body.	
In this case, the electric currents:	
☐ are arranged in different directions	
☐ are arranged mostly in one direction	. .mostly in one direction

19.	
In most substances the electric currents are arranged in many different directions. In other words, the pattern of the electric currents is irregular.	
In some substances the electric currents tend to be arranged most strongly in one direction. In this type of substance, the pattern of the electric currents is regular.	
Electrons flow from a negatively charged body through a conductor towards a positively charged body.	
The pattern of electric current in the conductor is:	
☐ irregular	
☐ regular	regular
If the free electrons in a body jump from atom to atom in all different directions, the pattern of electric current in that body is:	
☐ irregular	irregular
☐ regular	

20.

PREVIEW

In the following frames you will learn about the different effects of regular and irregular electric currents.

Although we cannot see the various types of electric currents, scientists have discovered ways of detecting whether the pattern of currents in any given substance is regular or irregular.

Even the most regular current patterns in a substance are complicated. But since we want to study current patterns, we will represent the currents with the following signs:

○— ○— ○— ○—

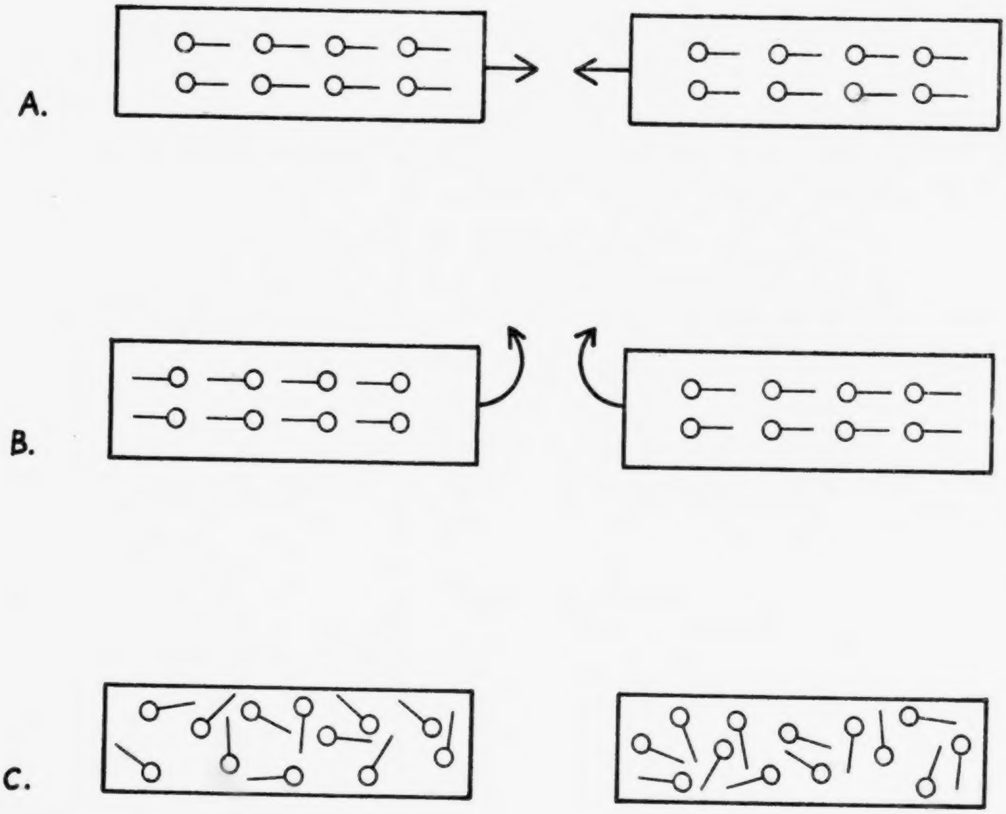
These signs or symbols are not pictures of currents. They just tell us that electric currents are present. The symbols are also used to show the direction of the currents.

In the following frames we will use other symbols which you have used before.

NO RESPONSE REQUIRED

GO ON TO NEXT FRAME

PANEL 2



21.	
LOOK at Panel 2.	
Each of the three diagrams in the Panel show two bars of metal placed next to each other.	
In which diagram(s) are the bars of metal represented as having regular current patterns?	
☐ A	A
☐ B	B
☐ C	
In which diagram(s) are the bars of metal represented as having irregular current patterns?	
☐ A	
☐ B	
☐ C	C

22.	
LOOK at Panel 2.	
In A and B the adjacent bars of metal are shown to have regular current patterns.	
In A the regular current patterns in the two adjacent bars:	
☐ are lined up in opposite directions	
☐ are lined up in the same direction	. . . the same direction
Diagram A also indicates that the ends of the two adjacent bars are:	
☐ attracting one another	attracting one another
☐ neither attracting nor repelling	
☐ repelling one another	
In B the current patterns in the two adjacent bars:	
☐ are lined up in opposite directions	. . . opposite directions
☐ are lined up in the same direction	
The ends of the two adjacent bars in B are:	
☐ attracting one another	
☐ neither attracting nor repelling	
☐ repelling one another	repelling one another
In C the current patterns in the bars are irregular. The ends of the two bars are:	
☐ attracting one another	
☐ neither attracting nor repelling	neither attracting nor . . .
☐ repelling one another	

23.

LOOK at Panel 2.

On the basis of the diagrams, it appears that there is a force of attraction between the ends of the two metal bars when there are:

- ☐ irregular current patterns in both bars
- ☐ regular current patterns that are lined up in opposite directions in both bars
- ☐ regular current patterns that are lined up in the same direction in both bars

There is a force of repulsion between the ends of the two bars when there are:

- ☐ irregular current patterns in both bars
- ☐ regular current patterns that are lined up in opposite directions in both bars
- ☐ regular current patterns that are lined up in the same direction in both bars

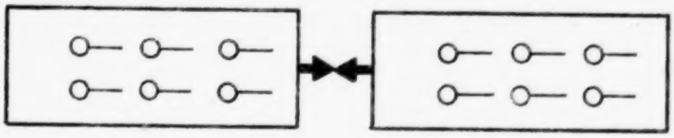
. . . the same direction . . .

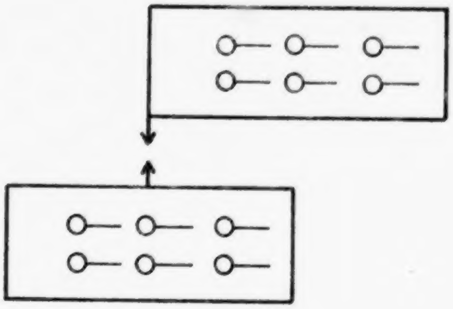
. . . opposite directions . .

24.	
When two metal bars, each with a regular current pattern, are placed end to end, and their patterns are lined up in the same direction, the ends of the bars:	
☐ attract one another	attract one another
☐ neither attract nor repel one another	
☐ repel one another	
When two metal bars, each with a regular current pattern, are placed end to end and their patterns are lined up in opposite directions, the ends of the bars:	
☐ attract one another	
☐ neither attract nor repel one another	
☐ repel one another	repel one another
When two metal bars, each with irregular current patterns, are placed end to end, the ends of the bars:	
☐ attract one another	
☐ neither attract nor repel one another	neither attract nor repel . . .
☐ repel one another	

25. As you may have already guessed, some of the bars of metal shown in Panel 2 were magnets. From what you have learned in the last few frames, a magnet is a bar of metal with: ☐ an irregular current pattern ☐ a regular current pattern	a regular current . . .

26.





Each picture above shows two magnets.

In the first figure, the magnets are set end to end. In the second figure, the ends of the magnets overlap, so that the end of one is opposite the middle of the other.

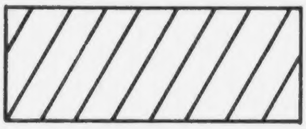
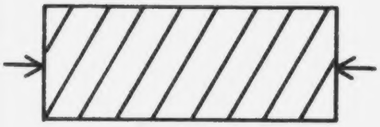
The pictures illustrate that the greatest degree of force is between:

☐ the end of one magnet and the end of another

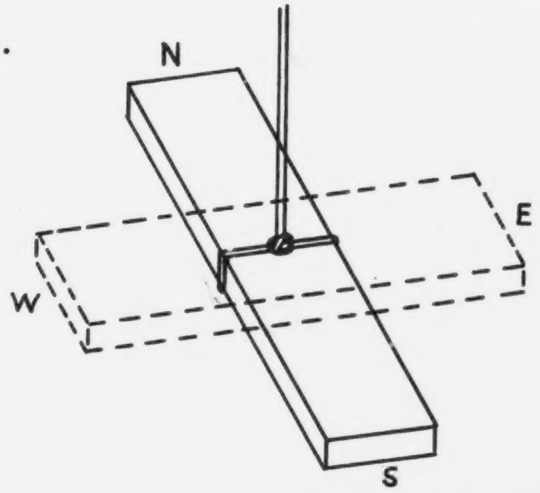
☐ the end of one magnet and the middle of another

. . . and the end of another

27. The ends of a magnet, where the force is concentrated, are called the poles. How many poles are there in a magnet? ________	2

28. DRAW an arrow to each pole in the magnet shown below: 	

29.



If a string is attached to the middle of a bar magnet, and the magnet is allowed to swing free, the magnet will begin to turn, as shown above.

The picture shows that the bar magnet will come to rest when:

- ☐ one pole is pointing to the east
- ☐ one pole is pointing to the north
- ☐ one pole is pointing to the south
- ☐ one pole is pointing to the west

. . . to the north

. . . to the south

30.

The pole of a magnet that turns to the north when the magnet swings free is called the north-seeking pole, or north pole. The other pole of that magnet:

☐ also turns to the north

☐ turns to the south

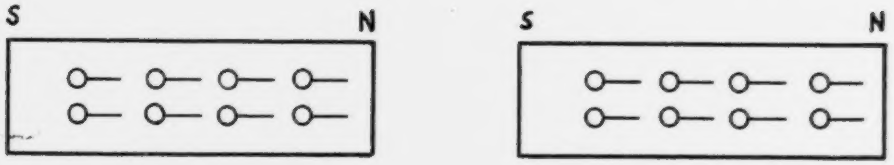
turns to the south

31.	
The pole of a magnet that turns to the south, when the magnet is swinging free:	
☐ is called the south-seeking, or south pole	is called the south- . . .
☐ is not called the south-seeking, or south pole	
A magnet has a(n):	
☐ east pole	
☐ north pole	north pole
☐ south pole	south pole
☐ west pole	

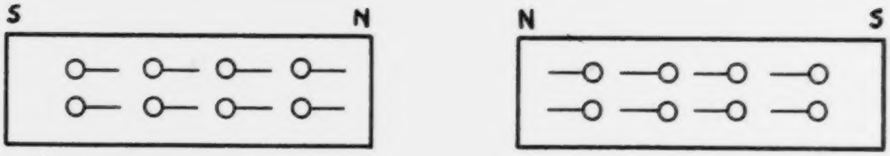
32.	
If two magnets were put end to end with the current patterns lined up in the same direction, then the two poles next to each other would:	
☐ attract one another	attract one another
☐ neither attract nor repel one another	
☐ repel one another	
If the current patterns of two magnets were lined up in opposite directions, then the two ends next to each other would:	
☐ attract one another	
☐ neither attract nor repel one another	
☐ repel one another	repel one another

PANEL 3

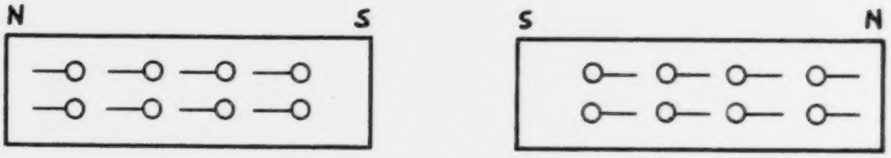
A.



B.



C.



33.

LOOK at Panel 3.

Each diagram in the Panel shows two magnets.

In A the current patterns in each of the two magnets are lined up in the same direction.

In A the north pole of one magnet is adjacent to the south pole of the other magnet.

The adjacent poles are:

- ☐ alike
- ☐ not alike

In B and C the current patterns in each of the two magnets are lined up in:

- ☐ opposite directions
- ☐ the same direction

In B and C the adjacent poles are:

- ☐ alike
- ☐ not alike

not alike

opposite directions

alike

34.

LOOK at Panel 3.

LOOK at the poles and the directions of the current patterns in the diagrams. You can see that when the adjacent poles of two magnets are unlike (not alike), the current patterns of the two magnets:

☐ are lined up in opposite directions

☐ are lined up in the same direction

When the adjacent poles of two magnets are alike the current patterns of the two magnets:

☐ are lined up in opposite directions

☐ are lined up in the same direction

. . .the same direction

. . .in opposite directions

35.	
As you have seen, when the adjacent poles of two magnets are not alike, the current patterns are lined up in the same direction.	
Thus, unlike poles will:	
☐ attract one another	attract one another
☐ repel one another	
When the adjacent poles of two magnets are alike, the current patterns are lined up in opposite directions.	
Thus, like poles will:	
☐ attract one another	
☐ repel one another	repel one another

36.	
For magnets, the general rule is that there is a force of attraction between:	
☐ like poles	
☐ unlike poles	unlike poles
And a force of repulsion between:	
☐ like poles	like poles
☐ unlike poles	

37.

The reason that one pole of a free-swinging bar magnet points north and the other points south is that the earth itself is a giant magnet.

The north-seeking pole of the magnet turns to:

- ☐ the north pole of the earth
- ☐ the south pole of the earth

The south-seeking pole of the magnet turns to:

- ☐ the north pole of the earth
- ☐ the south pole of the earth

the north pole of . . .

the south pole of . . .

38. The fact that the north pole of a magnet will point at the north pole of the earth when allowed to swing freely is the basis for the operation of a compass. A compass is actually a small, lightweight magnet. The reason that a compass works is that: ☐ both the compass and the earth are magnets ☐ only the compass is a magnet ☐ only the earth is a magnet	both the compass and . . .

39.

PREVIEW

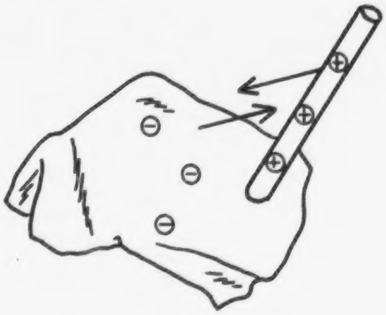
In the preceding frames you have learned about magnetic forces of attraction and repulsion. We will study these forces again. But now we will consider other sources of forces of attraction or repulsion.

NO RESPONSE REQUIRED

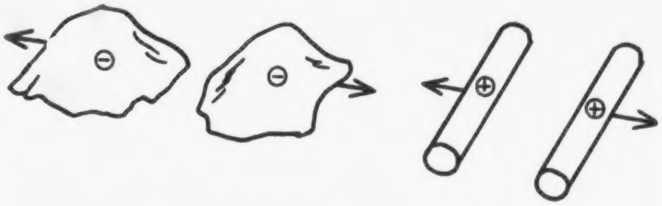
GO ON TO NEXT FRAME

40.	
REVIEW	
Mass is the amount or substance in a body of matter.	
Mass is a property of:	
☐ all bodies	all bodies
☐ only some bodies	
An electrically charged body is one which has either an excess or a deficiency of electrons.	
Which is correct?	
☐ all bodies are electrically charged	
☐ only some bodies are electrically charged	only some bodies are . . .
All substances have electric currents associated with electron movements.	
Regular electric current patterns are found in:	
☐ all bodies	
☐ only some bodies	only some bodies

41.	
Every body of matter made up of many atoms tends to be electrically neutral - that is, it tends to have the same number of electrons and protons, in the same way that a single atom has the same number of electrons and protons.	
You can guess that, if a body has fewer electrons than protons, it will:	
☐ not tend to obtain or get rid of electrons	
☐ tend to get rid of electrons	
☐ tend to obtain electrons	tend to obtain electrons
And that, if a body has too many electrons, it will:	
☐ not tend to obtain or get rid of electrons	
☐ tend to get rid of electrons	tend to get rid of . . .
☐ tend to obtain electrons	

42 .	
	
When a glass rod and a piece of silk are rubbed together, the rod becomes positively charged and the silk becomes negatively charged.	
The rod will then tend to: ☐ gain electrons ☐ lose electrons	gain electrons
The silk will then tend to: ☐ gain electrons ☐ lose electrons	lose electrons
The picture above shows a glass rod and a piece of silk after they have been rubbed together.	
The rod and the silk: ☐ attract one another ☐ repel one another	attract one another

43.	
In the picture in the previous frame, the glass rod has a positive charge and the piece of silk has a negative charge.	
That is, the charges of the two bodies are:	
☐ alike	
☐ not alike	not alike
It appears that there is a force of attraction between bodies that have:	
☐ like charges	
☐ unlike charges	unlike charges

44.	
	
Suppose there are two pieces of silk, each with too many electrons, as shown on the left above.	
What happens to the pieces of silk?	
☐ they attract one another	
☐ they repel one another	they repel one another
Now, suppose there are two glass rods, each with too few electrons, as shown on the right.	
What happens to the glass rods?	
☐ they attract one another	
☐ they repel one another	they repel one another
That is, there is a force of repulsion between bodies that have:	
☐ like charges	like charges
☐ unlike charges	

45.

Bodies with like charges:

- ☐ attract one another
- ☐ repel one another

Bodies with unlike charges:

- ☐ attract one another
- ☐ repel one another

repel one another

attract one another

46.

PREVIEW

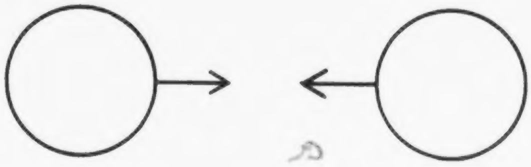
In the preceding frames we have briefly learned that electrically charged bodies exert forces of attraction or repulsion.

In the following frames we will look at forces between bodies that are not electrically charged.

NO RESPONSE REQUIRED

GO ON TO NEXT FRAME

47.



The picture above shows two bodies. Neither body is electrically charged.

What is happening to the two bodies?

- ☐ they are attracting one another
- ☐ they are neither attracting nor repelling one another
- ☐ they are repelling one another

.attracting one another

48.	
Why should two bodies that have no charge attract one another?	
Because two bodies will attract one another merely on the basis of their mass, whether or not they have any charge. An example is the attraction between the earth and the sun. Another example is the attraction between you and the earth.	
Do all bodies have mass?	
☐ yes	yes
☐ no	
Thus, you can guess that, on the basis of mass, there is an attraction between:	
☐ any two bodies	any two bodies
☐ only some bodies	
This means that there would be such a force between:	
☐ two bodies with charges	two bodies with charges
☐ two bodies with no charges	two bodies with no charges

49.

FOOTNOTE FRAME

When there are two bodies with like charges, there will be a force of repulsion between them on the basis of their charge, but there will also be a force of attraction between them on the basis of their mass. Whether they end up attracting or repelling one another will depend on which force is greater.

When there are two bodies with unlike charges, there will be two forces of attraction between them - one based on charge and the other based on mass - and, thus, the bodies will attract one another.

NO RESPONSE REQUIRED

GO ON TO NEXT FRAME

50. Considering only mass, two bodies will: ☐ attract one another ☐ neither attract nor repel one another ☐ repel one another	attract one another

51.

A force of attraction occurs between:	
☐ any two bodies, on the basis of mass	any two bodies, on the . . .
☐ like poles of two magnets	
☐ two bodies with like charges	
☐ two bodies with unlike charges	two bodies with unlike . . .
☐ unlike poles of two magnets	unlike poles of two . . .
A force of repulsion occurs between:	
☐ any two bodies, on the basis of mass	
☐ like poles of two magnets	like poles of two magnets
☐ two bodies with like charges	two bodies with like charges
☐ two bodies with unlike charges	
☐ unlike poles of two magnets	

Time completed ___________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

ELECTRIC CHARGE	an excess or deficiency of electrons in a body.
NEGATIVE CHARGE	an excess of electrons in a body.
POSITIVE CHARGE	a deficiency of electrons in a body.
FREE ELECTRONS	the electrons in the outermost orbit of an atom.
ELECTRIC CURRENT	the movement of electrons in a body.
CONDUCTOR	a substance through which free electrons can flow from a point of excess electrons to a point of few electrons.
IRREGULAR PATTERN OF CURRENTS	the movement of electrons in many directions in a body.
REGULAR PATTERN OF CURRENTS	the movement of electrons in the same general direction in a body.
MAGNET	a body with a regular current pattern.
MAGNETIC POLES	the ends of a magnet at which the magnetic forces are concentrated.
NORTH POLE	that pole of a magnet which seeks the north pole of the earth.
SOUTH POLE	that pole of a magnet which seeks the south pole of the earth.
COMPASS	a small, lightweight magnet that can swing freely and thus point at the north pole of the earth.
MASS	the amount of substance in a body.
RULE FOR FORCES BETWEEN MAGNETS	Unlike poles attract, like poles repel.
RULE FOR FORCES BETWEEN CHARGED BODIES	Unlike charges attract, like charges repel.
RULE FOR FORCES BETWEEN ANY TWO BODIES, ON BASIS OF MASS	Any two bodies attract one another.

MASTERY TEST

Time started ____________

1. In which of the following cases are electric currents produced:

   a. ☐ A negatively charged particle jumps from the orbit of one atom to that of another.

   b. ☐ A rock is thrown high into the air and falls to earth again.

   c. ☐ An electron circles the nucleus of an atom in an orbit.

   d. ☐ Electrons move from one body towards another in a conductor.

2. A magnet is a piece of metal in which the electric currents are:

   a. ☐ arranged in irregular patterns

   b. ☐ arranged in many different directions

   c. ☐ arranged mostly in one direction

   d. ☐ regular in pattern

3. In which one or more of the following cases do the two bodies repel each other?

   a. ☐ A negatively charged body is adjacent to another negatively charged body.

   b. ☐ A positively charged body is near another positively charged body.

   c. ☐ A positively charged body is next to a negatively charged body.

   d. ☐ An uncharged body is near another uncharged body.

   e. ☐ The north poles of two magnets are near each other.

   f. ☐ The south pole of one magnet is near the north pole of another magnet.

4. Scientists can measure a force of attraction between:

   a. ☐ any two bodies, on the basis of mass;

   b. ☐ the north poles of two magnets;

   c. ☐ two bodies with like charges;

   d. ☐ two bodies with unlike charges;

   e. ☐ unlike poles of two magnets.

Time completed ______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 389-872

ED 070909

PM 431 - 65

ADVANCED
GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

ELECTRICAL, MAGNETIC, AND GRAVITATIONAL FIELDS
LEVEL: II
UNIT: 9
LESSON: 5

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

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1. PREVIEW In the following unit we will continue our study of the different physical forces which have been discovered in our world. NO RESPONSE REQUIRED	GO ON TO NEXT FRAME

2.

Everyone is familiar with the word "gravity." Gravity is what makes things heavy and causes things to fall.

What we call gravity in everyday life is actually the force of attraction between the earth and any object because of their mass. This gravitational force is what makes bodies, including you, cling to the earth, even though the earth is spinning through space. It is also the force that makes the earth circle around the sun.

Gravitational forces occur between bodies on the basis of their:

☐ charge

☐ current pattern

☐ mass

mass

3.	
Gravitational forces occur between bodies because of their mass.	
Do all bodies have mass?	
☐ yes	yes
☐ no	
Gravitational forces are exerted by:	
☐ all bodies	all bodies
☐ only some bodies	

4.	
REVIEW	
Magnets are substances in which the electric currents occur in:	
☐ an irregular pattern	
☐ a regular pattern	a regular pattern
That is, the force of a magnet results from:	
☐ an excess or deficiency of electrons in the substance	
☐ the movement of electrons in the substance	the movement of . . .
An electrically charged body is one which has:	
☐ different numbers of electrons and protons	different numbers of . . .
☐ the same number of electrons and protons	

5.	
The force of a charged body depends on the difference between the number of protons and electrons in that body.	
A body with a deficiency of electrons is:	
☐ negatively charged	
☐ not charged	
☐ positively charged	positively charged
A body with an excess of electrons is:	
☐ negatively charged	negatively charged
☐ not charged	
☐ positively charged	
The force of a charged body is called an electrostatic force.	
You can guess that electrostatic forces are exerted by:	
☐ all charged bodies	all charged bodies
☐ only negatively charged bodies	
☐ only positively charged bodies	
The force of a magnet is called an electromagnetic force.	
Electromagnetic forces occur between bodies on the basis of their:	
☐ charge	
☐ current pattern	current pattern
☐ mass	

6.	
Are all bodies charged?	
☐ yes	
☐ no	no
Therefore, electrostatic forces are exerted by:	
☐ all bodies	
☐ some bodies	some bodies
Do all bodies have regular current patterns?	
☐ yes	
☐ no	no
Therefore, electromagnetic forces are exerted by:	
☐ all bodies	
☐ some bodies	some bodies

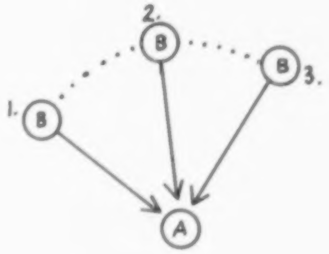
7.

MATCH the columns below to indicate the definition of each type of force listed on the right:

A. force between two bodies on the basis of charge	1. _____ electromagnetic force	1. B
B. force between two bodies on basis of current pattern	2. _____ electrostatic force	2. A
C. force between two bodies on the basis of mass	3. _____ gravitational force	3. C

8.	
All bodies exert a (n):	
☐ electromagnetic force	
☐ electrostatic force	
☐ gravitational force	gravitational force
Only some bodies exert a (n):	
☐ electromagnetic force	electromagnetic force
☐ electrostatic force	electrostatic force
☐ gravitational force	

9.



The picture above shows two bodies, Body A and Body B. Body A is exerting a gravitational force on Body B. The picture shows Body B at each of three different points in the space around Body A.

The picture shows that Body A exerts a gravitational force on Body B when Body B is at:

☐ Point 1

☐ Point 2

☐ Point 3

Thus, the exertion of a gravitational force by Body A:

☐ depends on the position of Body B

☐ does not depend on the position of Body B

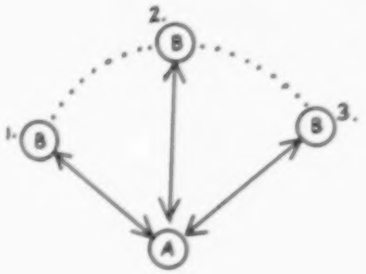
Point 1

Point 2

Point 3

does not depend on . . .

10.



Now, suppose that Body A and Body B are charged bodies and that the force exerted by Body A is an electrostatic force, instead of a gravitational force. The electrostatic force could be a force of attraction or of repulsion, as shown by the arrows.

The picture shows that Body A exerts an electrostatic force on Body B when Body B is at:

☐ Point 1

☐ Point 2

☐ Point 3

Thus, the exertion of an electrostatic force by Body A:

☐ depends on the position of Body B

☐ does not depend on the position of Body B

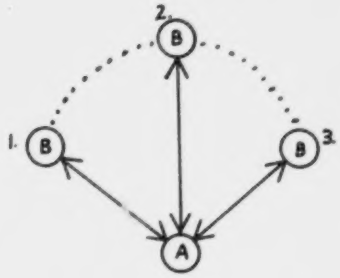
Point 1

Point 2

Point 3

does not depend on . . .

11.



Now, suppose that Body A and Body B are magnets and that the force exerted by Body A is an electromagnetic force. Again, the force could be one of attraction or of repulsion.

The picture shows that Body A exerts an electromagnetic force on Body B when Body B is at:

- ☐ Point 1
- ☐ Point 2
- ☐ Point 3

Thus, the exertion of an electromagnetic force by Body A:

- ☐ depends on the position of Body B
- ☐ does not depend on the position of Body B

Point 1

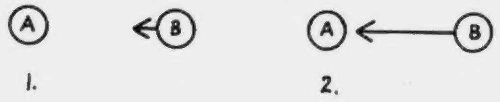
Point 2

Point 3

does not depend on . . .

12.	
Gravitational force is exerted by any body upon another:	
☐ at all points in the space around the body	at all points in space . . .
☐ at some points in the space around the body	
Electrostatic force is exerted by a charged body upon another:	
☐ at all points in the space around the body	at all points in space . . .
☐ at some points in the space around the body	
Electromagnetic force is exerted by one magnet upon another:	
☐ at all points in the space around the magnet	at all points in space . . .
☐ at some points in the space around the magnet	

13.



As you have seen, arrows are used to indicate the force between two bodies.

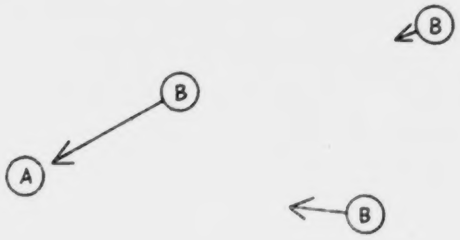
The force between two bodies can vary in strength. How strong the force is can be indicated by the length of the arrows. The longer the arrows, the greater the force.

In the pictures above, the force exerted by Body A on Body B is:

- ☐ greater in diagram 1 than in diagram 2
- ☐ greater in diagram 2 than in diagram 1
- ☐ the same in both pictures

greater in diagram 2 than...

14.



The picture above shows what happens to the strength of the gravitational force exerted by Body A on Body B as the position of Body B is changed.

The picture shows that the gravitational force between the two bodies increases as the distance between them:

☐ decreases

☐ increases

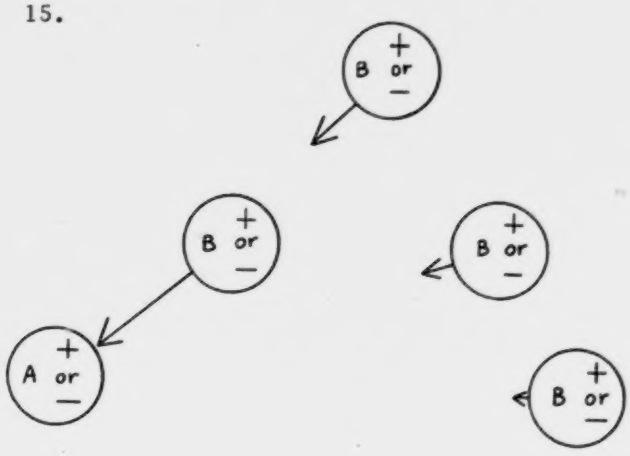
And that the gravitational force decreases as the distance:

☐ decreases

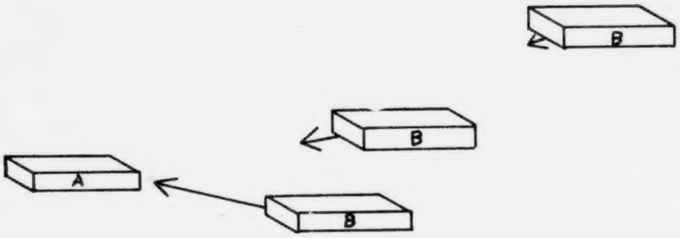
☐ increases

decreases

increases

15.  A similar picture can be drawn for two charged bodies, A and B, as shown above. A or B can be either negatively or positively charged. The picture shows that the electrostatic force between two charged bodies increases as the distance between them: ☐ decreases ☐ increases	decreases
And that the electrostatic force decreases as the distance: ☐ decreases ☐ increases	increases

16.



The picture above shows two magnets.

This picture shows that the electromagnetic force between two magnets increases as the distance between them:

☐ decreases

☐ increases

And that the electromagnetic force decreases as the distance:

☐ decreases

☐ increases

decreases

increases

17.

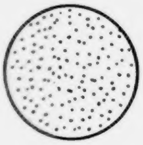
The relationship between strength of force and distance is:

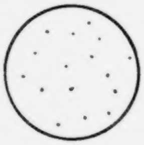
- ☐ different for gravitational, electrostatic and electromagnetic forces
- ☐ similar for gravitational, electrostatic and electromagnetic forces

similar for gravitational . . .

18.	
As the distance between any two bodies increases, the gravitational force between them: ☐ decreases ☐ increases ☐ remains the same	decreases
As the distance between two charged bodies increases, the electrostatic force between them: ☐ decreases ☐ increases ☐ remains the same	decreases
As the distance between two magnets increases, the electromagnetic force between them: ☐ decreases ☐ increases ☐ remains the same	decreases

19.





Bodies vary in mass; some bodies have more mass than others.

The size of a body is not necessarily an indication of its mass. For example, a giant balloon filled with air does not have very much mass; it has less mass than a body of lead the size of a basketball.

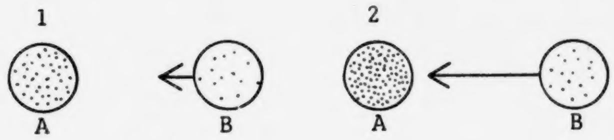
The amount of mass in a body can be represented by dots. The closer the dots, the greater the amount of mass.

Which body shown above has more mass?

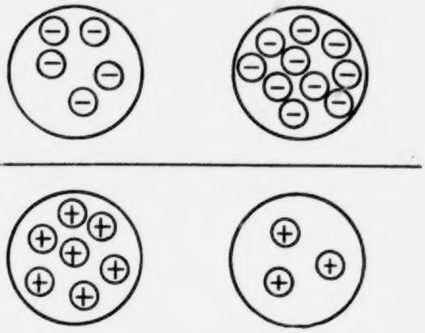
☐ body on left

☐ body on right

body on left

20.	
 	
The two pictures above show the gravitational force exerted by Body A on Body B. The mass of Body A is different in the two pictures. The mass of Body A is greater in: ☐ Diagram 1 ☐ Diagram 2	Diagram 2
The pictures show that Body A exerts a greater gravitational force when its mass is: ☐ greater ☐ smaller	greater
Suppose the mass of Body A were the same in both cases, but the mass of Body B changed. You can guess that the gravitational force between the two bodies would be greater when the mass of Body B was: ☐ greater ☐ smaller	greater
Thus, the gravitational force between Body A and Body B changes: ☐ only when there is a change in the mass of Body A ☐ only when there is a change in the mass of Body B ☐ when there is a change in the mass of either body	. . . of either body

21.



Just as the mass can vary from one body to another, so can the strength of a charge vary from one charged body to another. Some bodies have stronger charges than others.

The strength of the charge depends on the number of electrons lost or gained by the body. This can be represented by the number of plus or minus signs drawn inside the body. The greater the number of signs, the greater the charge.

Which of the two bodies in the upper row above has the greater negative charge?

☐ body on left

☐ body on right

Which of the two bodies in the lower row has the greater positive charge?

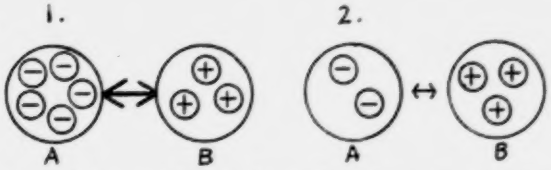
☐ body on left

☐ body on right

body on right

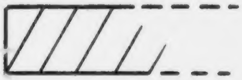
body on left

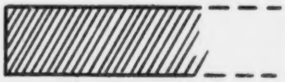
22



The two pictures above show the electrostatic force exerted by Body A on Body B. In this illustration, Body A and Body B have opposite charges, but they could have the same charge, and the force could be one of repulsion instead of one of attraction.	
The strength of Body A's charge is different in the two pictures. The charge of Body A is stronger in:	
☐ Diagram 1	Diagram 1
☐ Diagram 2	
The pictures show that Body A exerts a greater electrostatic force when its charge is:	
☐ greater	greater
☐ smaller	
You can guess that, if it were the charge of Body B that changed instead of that of Body A, the electrostatic force between the two bodies would be greater when the charge of Body B was:	
☐ greater	greater
☐ smaller	
Thus, the electrostatic force between Body A and Body B changes:	
☐ only when there is a change in the strength of charge of Body A	
☐ only when there is a change in the strength of charge of Body B	
☐ when there is a change in the strength of charge of either body	. . . of either body

23.





The electromagnetic force exerted by a magnet can vary from one magnet to another. This variation depends on the regularity of the current pattern in the magnet. The more regular the pattern, the greater the force the magnet will exert. The strength of a magnet is measured by the amount of force exerted at the poles. This strength is called pole-strength.

The pole-strength of a magnet can be represented by a series of lines drawn across the pole. The closer the lines, the greater the pole-strength.

Which pole shown above has the greater strength?

☐ pole on left

☐ pole on right

pole on right

24.	
As the mass of either of two bodies increases, the gravitational force between them:	
☐ decreases	
☐ increases	increases
☐ remains the same	
As the charge on either of two bodies increases, the electrostatic force between them:	
☐ decreases	
☐ increases	increases
☐ remains the same	
As the pole-strength of either of two magnets increases, the electromagnetic force between them:	
☐ decreases	
☐ increases	increases
☐ remains the same	

25.

As you have seen, when the mass of either of two bodies is increased, the gravitational force between them increases.

Suppose the mass of each of two bodies is doubled. You would expect the force between them also to be doubled. But, in fact, it will be four times greater.

In other words, the gravitational force between two bodies depends, not on the sum of their masses, but on the product of their masses. An increase in mass makes for a much larger increase in gravitational force.

Suppose the mass of each of two bodies is tripled. The gravitational force between the two bodies will be:

- ☐ 3 times greater
- ☐ 6 times greater
- ☐ 9 times greater

9 times greater

26.

In a similar way, when the charge of each of two bodies is doubled, the resulting electrostatic force is four times greater. That is, the electrostatic force between two charged bodies depends, not on the sum of their charges, but on the product of the charges. An increase in charge makes for a much larger increase in electrostatic force.

Suppose the charge of each of two bodies is made 4 times greater. The electrostatic force between the two bodies will be:

- ☐ 4 times greater
- ☐ 8 times greater
- ☐ 16 times greater
- ☐ 64 times greater

16 times greater

27.

With magnets also, the strength of force depends on the product of the pole-strengths of the magnets, not on the sum of the pole-strengths.

Thus, if the pole-strength of each of two magnets is made 5 times greater, the resulting electromagnetic force will be:

☐ 5 times greater

☐ 10 times greater

☐ 25 times greater

☐ 125 times greater

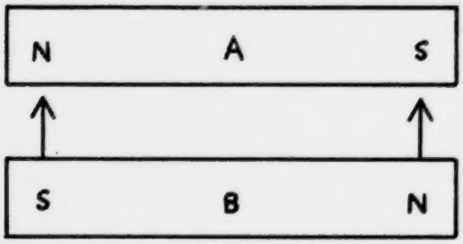
☐ 625 times greater

25 times greater

28.

The gravitational force between any two bodies is stated as:	
☐ the product of their masses	the product of . . .
☐ the sum of their masses	
The electrostatic force between two charged bodies is stated as:	
☐ the product of their charges	the product of . . .
☐ the sum of their charges	
The electromagnetic force between two magnets is stated as:	
☐ the product of their pole-strengths	the product of . . .
☐ the sum of their pole-strengths	

29.



In the previous frames, the force between two magnets has been illustrated by showing the force between a pole of one and a pole of the other.	
But, every magnet has two poles. You can see from the diagram above that the north pole of Magnet A attracts:	
☐ the north pole of Magnet B	
☐ the south pole of Magnet B	the south pole . . .
And that the south pole of Magnet A attracts:	
☐ the north pole of Magnet B	the north pole . . .
☐ the south pole of Magnet B	
Thus, the force exerted by one magnet on another consists of:	
☐ the force exerted by one of its poles	
☐ the forces exerted by both of its poles	. . . both of its poles

30.

You have learned that one body exerts a gravitational force upon another at every point in the surrounding space, that a gravitational force is weaker the greater the distance In other words, there is a pattern of gravitational forces around every body.

What are the characteristics of the pattern of electrostatic forces around a charged body?

☐ The forces are attractions only.	
☐ The forces are attractions or repulsions.	. . . or repulsions.
☐ The forces are exerted at all points.	. . . exerted at all points.
☐ The forces are exerted only at some points.	
☐ The forces are repulsions only.	
☐ The forces grow stronger the greater the distance.	
☐ The forces grow weaker the greater the distance.	. . . grow weaker . . . .

31.

What are the characteristics of the pattern of electromagnetic forces around a magnet?

☐ The force is exerted by one pole only.	
☐ The force is exerted by two poles.	. . . exerted by two poles.
☐ The forces are attractions only.	
☐ The forces are attractions or repulsions.	. . . or repulsions.
☐ The forces are exerted at all points.	. . . exerted at all points.
☐ The forces are exerted only at some points.	
☐ The forces are repulsions only.	
☐ The forces grow stronger the greater the distance.	
☐ The forces grow weaker the greater the distance.	. . . grow weaker . . . .

32.	
The pattern of forces around a body is called a field. The body that gives rise to the forces is called the source of the field.	
The source of a gravitational field is:	
☐ a charged body only	
☐ any body	any body
☐ only a body with regular current patterns	
The source of an electromagnetic field is:	
☐ a charged body only	
☐ any body	
☐ only a body with regular current patterns	. . . regular current patterns
The source of an electrostatic field is:	
☐ a charged body only	a charged body only
☐ any body	
☐ only a body with regular current patterns	

33.

A field is:

☐ the pattern of forces around a body

☐ the body that gives rise to forces

A source is:

☐ the pattern of forces around a body

☐ the body that gives rise to forces

the pattern of forces . . .

the body that gives rise . . .

34.

MATCH the columns below to indicate the description of each field listed on the right:

A. pattern of forces around a body with a regular current pattern	1. _____	electromagnetic field
B. pattern of forces around a charged body	2. _____	electrostatic field
C. pattern of forces around any body	3. _____	gravitational field

1. A
2. B
3. C

Time completed ____________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

ELECTROMAGNETIC FORCE	Force between two bodies on the basis of current pattern occurs between bodies with regular current patterns only.
ELECTROSTATIC FORCE	Force between two bodies on the basis of charge occurs between charged bodies only.
GRAVITATIONAL FORCE	Force between two bodies on the basis of mass occurs between any two bodies.
POLE-STRENGTH	strength of the electromagnetic force exerted by the pole of a magnet.
RELATIONSHIP BETWEEN FORCE AND DISTANCE	The smaller the distance between two bodies, the greater the force exerted by one upon the other. This rule applies to electromagnetic, electrostatic and gravitational forces.
RELATIONSHIP BETWEEN FORCE AND SURROUNDING SPACE	A force is exerted by a body at all points in the surrounding space. This rule applies to electromagnetic, electrostatic and gravitational forces.
RELATIONSHIP BETWEEN FORCE AND:	
MASS	The greater the mass of a body, the greater the gravitational force it exerts upon another body.
CHARGE	The greater the charge of a body, the greater the electrostatic force it exerts upon another body.
POLE-STRENGTH	The greater the pole-strength of a body, the greater the electromagnetic force it exerts upon another body.
FIELD	the pattern of forces around a body.
ELECTROMAGNETIC FIELD	the pattern of forces around a body with a regular current pattern.
ELECTROSTATIC FIELD	the pattern of forces around a charged body.
GRAVITATIONAL FIELD	the pattern of forces around any body, on the basis of its mass.
SOURCE	the body that gives rise to a field.

MASTERY TEST

Time started ______________

1. There are different types of forces of attraction or repulsion between bodies. MATCH the columns below to indicate the definition of each type of force listed on the right:

A. force between two bodies on the basis of current pattern

B. force between two charged bodies

C. force between the masses of two bodies

1. _____ electromagnetic force

2. _____ electrostatic force

3. _____ gravitational force

2. The gravitational force between two bodies decreases as the distance between them:

a. ☐ decreases

b. ☐ increases

As the distance between two charged bodies increases, the electrostatic force between them:

a. ☐ decreases

b. ☐ increases

The electromagnetic force between two magnets increases as the distance between them:

a. ☐ decreases

b. ☐ increases

3. Two bodies exert a gravitational force on each other. If the mass of one or both of the bodies were increased the force between them would:

a. ☐ decrease

b. ☐ increase

c. ☐ remain the same

3. (continued)

If the charge on either of two bodies increases, the electrostatic force between them:

a. ☐ decreases

b. ☐ increases

c. ☐ remains the same

If the pole-strength of either of two magnets decreases, the electromagnetic force between them:

a. ☐ decreases

b. ☐ increases

c. ☐ remains the same

4. Gravitational fields can be measured around:

a. ☐ a charged body only

b. ☐ any body

c. ☐ only a body with regular current patterns

The source of an electrostatic field is:

a. ☐ a charged body only

b. ☐ a magnet only

c. ☐ any body

4. (continued)

Electromagnetic fields are exerted by:

a. ☐ charged bodies only

b. ☐ all bodies

c. ☐ only bodies with regular current patterns

Time completed ________________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-873

ED 070909

PM 431 - 66

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

THE CONSERVATION AND CONVERSION OF MATTER AND ENERGY
LEVEL: II
UNIT: 9
LESSON: 6

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
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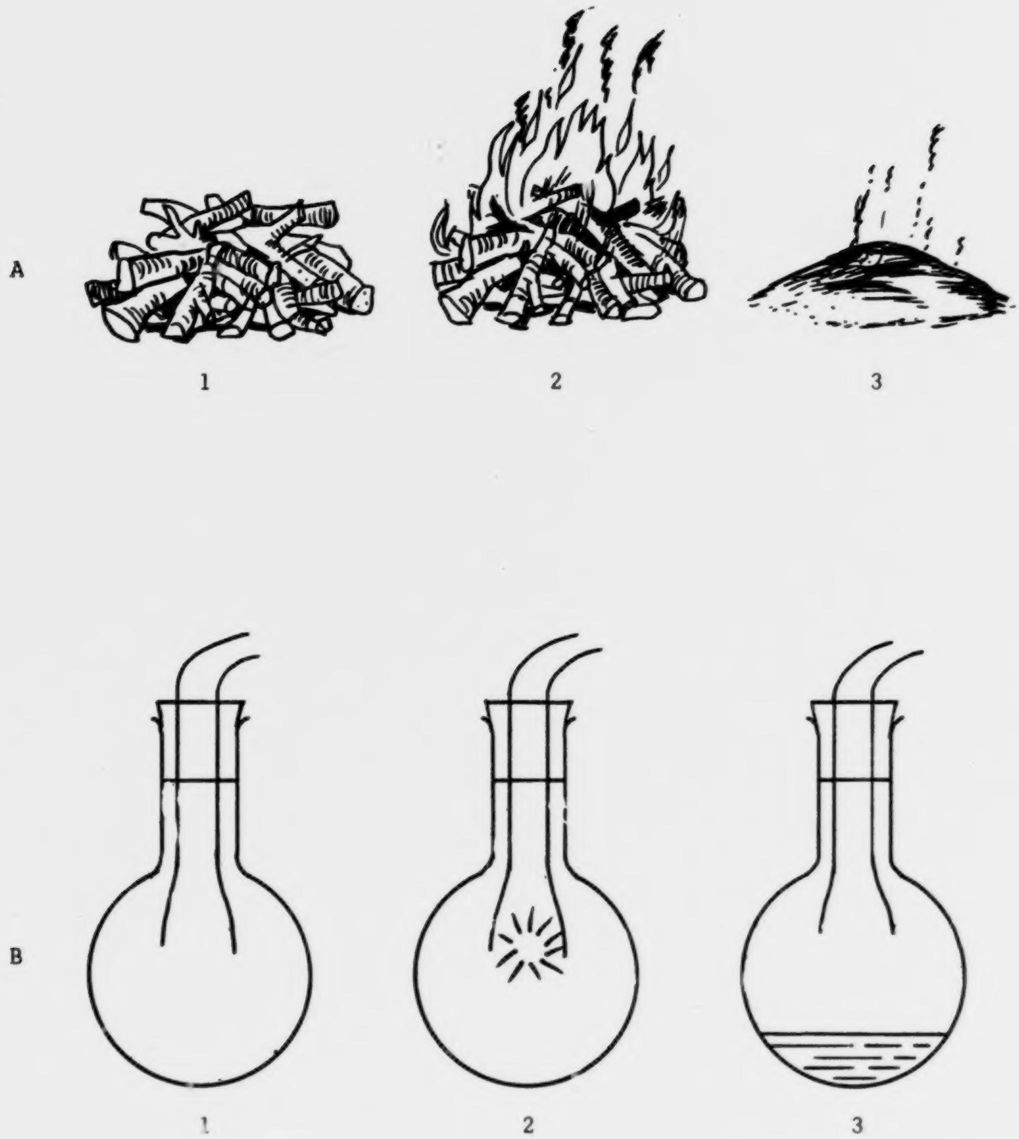
1. PREVIEW FRAME Among the most important laws of nature which physicists have discovered are those called "conservation principles." To conserve something is to keep it. Conservation principles are statements about things in nature that are kept — that never change. In this lesson, you will learn first about the conservation of matter. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
2. You already know that we measure matter by its mass. A given quantity of matter always has the same mass, no matter where it is — on the earth, on the moon, or in space. We use weight to represent mass. A given quantity of matter always has the same weight on earth (although it has a different weight on the moon). What happens to matter when it undergoes a physical change, such as melting, or being broken into small pieces? ☐ the form changes, but not the weight ☐ the weight changes, but not the form ☐ neither the weight nor the form change ☐ both the weight and the form change	the form changes . . .

PANEL 1



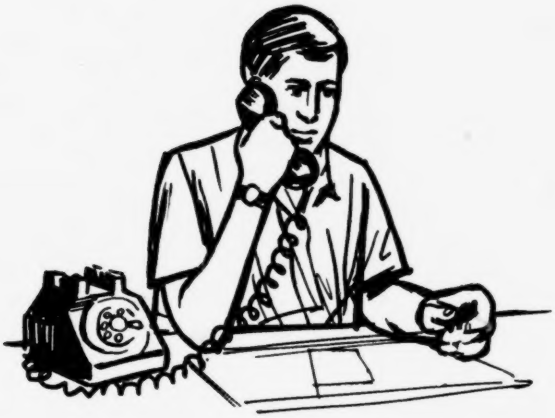
3. It is easy to see that physical changes do not affect the quantity of matter (which we measure by weight). Physicists say that matter is conserved. To conserve is to keep unchanged. "Matter is conserved" means: ☐ only that the quantity of matter does not increase ☐ only that the quantity of matter does not decrease ☐ that the quantity of matter does not increase or decrease Is matter conserved in physical changes? ☐ yes ☐ no	. . . does not increase or . . . yes
4. REFER TO PANEL 1 Matter is also conserved in chemical reactions, such as those shown in the panel, although this fact is not always obvious. In Drawing A, wood is burned. As a result, the quantity of matter seems to: ☐ decrease ☐ increase ☐ remain unchanged In Drawing B, hydrogen is burned in oxygen to produce water. We can see neither the hydrogen nor the oxygen, but we can see the water. As a result of the burning, the quantity of matter seems to: ☐ decrease ☐ increase ☐ remain unchanged	decrease increase

5. REFER TO PANEL 1 Until man learned about gases, he thought that fire actually destroyed matter. We know now that the reaction shown in Drawing A is really: air + wood → ashes + smoke + carbon dioxide + water vapor In a laboratory, you can weigh each substance - including the gases - very precisely. Suppose you started with exactly 10 pounds of wood and air. Since matter is conserved in chemical reactions, what should the total of all the products weigh ? ☐ a little less than 10 pounds ☐ a little more than 10 pounds ☐ exactly 10 pounds ☐ much less than 10 pounds ☐ much more than 10 pounds	exactly 10 pounds
6. REFER TO PANEL 1 Careful measurements of the weight of the raw materials and the products of chemical reactions always confirm the fact that matter is conserved. In Drawing B, suppose 2 grams of hydrogen have combined with 16 grams of oxygen. According to the Principle of the Conservation of Matter, how many grams of water are produced ? ________	18

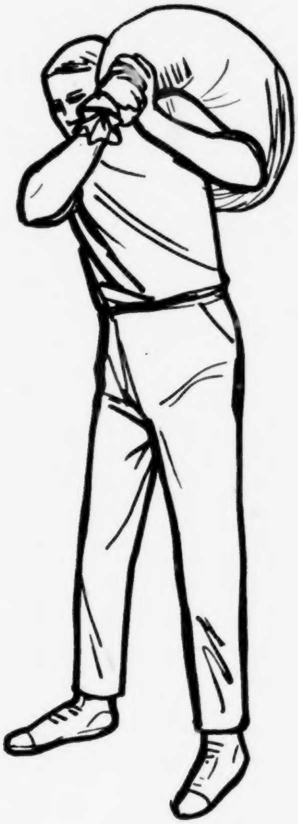
7. The Principle of the Conservation of Matter states that matter: ☐ can be created but not destroyed ☐ can be destroyed but not created ☐ can be both created and destroyed ☐ can be neither created nor destroyed	can neither be created nor . . .
8. FOOTNOTE FRAME In an earlier lesson, you learned about energy produced by nuclear reactions (fission and fusion). These reactions are the only exception to the Principle of the Conservation of Matter -- the energy released is produced by the destruction of minute quantities of matter. Such reactions are very rare on earth -- so rare that we can ignore them unless we are working in the field of nuclear physics. In a corner of your mind, you can keep this footnote to the Principle of the Conservation of Matter: "Matter can neither be created nor destroyed -- except in nuclear reactions." We will return briefly to this subject later in this lesson. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

9. To demonstrate that matter is conserved in a reaction which involves some kind of change in matter, we measure mass (or weight). Suppose we want to find out whether energy is conserved in a situation that involves some kind of energy change. What would we have to measure ? ☐ energy ☐ mass ☐ neither	energy
10. Energy is harder to measure than mass. You may remember that in an earlier lesson energy was defined as "ability to move matter." For the purposes of measurement, energy is more precisely defined as "ability to do work." The more work an object can do, the more energy it has. If we increase the energy of a substance or an object, it will be able to do more work. Conversely, when an object does work, it "spends" some of its energy. Before we can go on to discuss the conservation of energy, we must see how work -- and, therefore, energy -- are measured. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

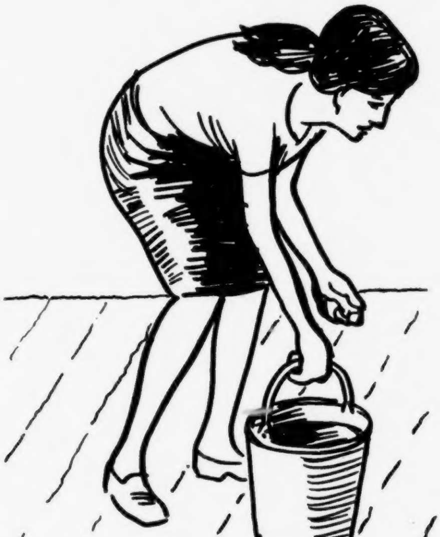
PANEL 2



A



B



C

11.

REFER TO PANEL 2

If you were asked which drawings show people doing work, you would probably say, "All three."

In the everyday meaning of the term "work," you would be right. But, once again, we have a word whose scientific meaning is much more exact.

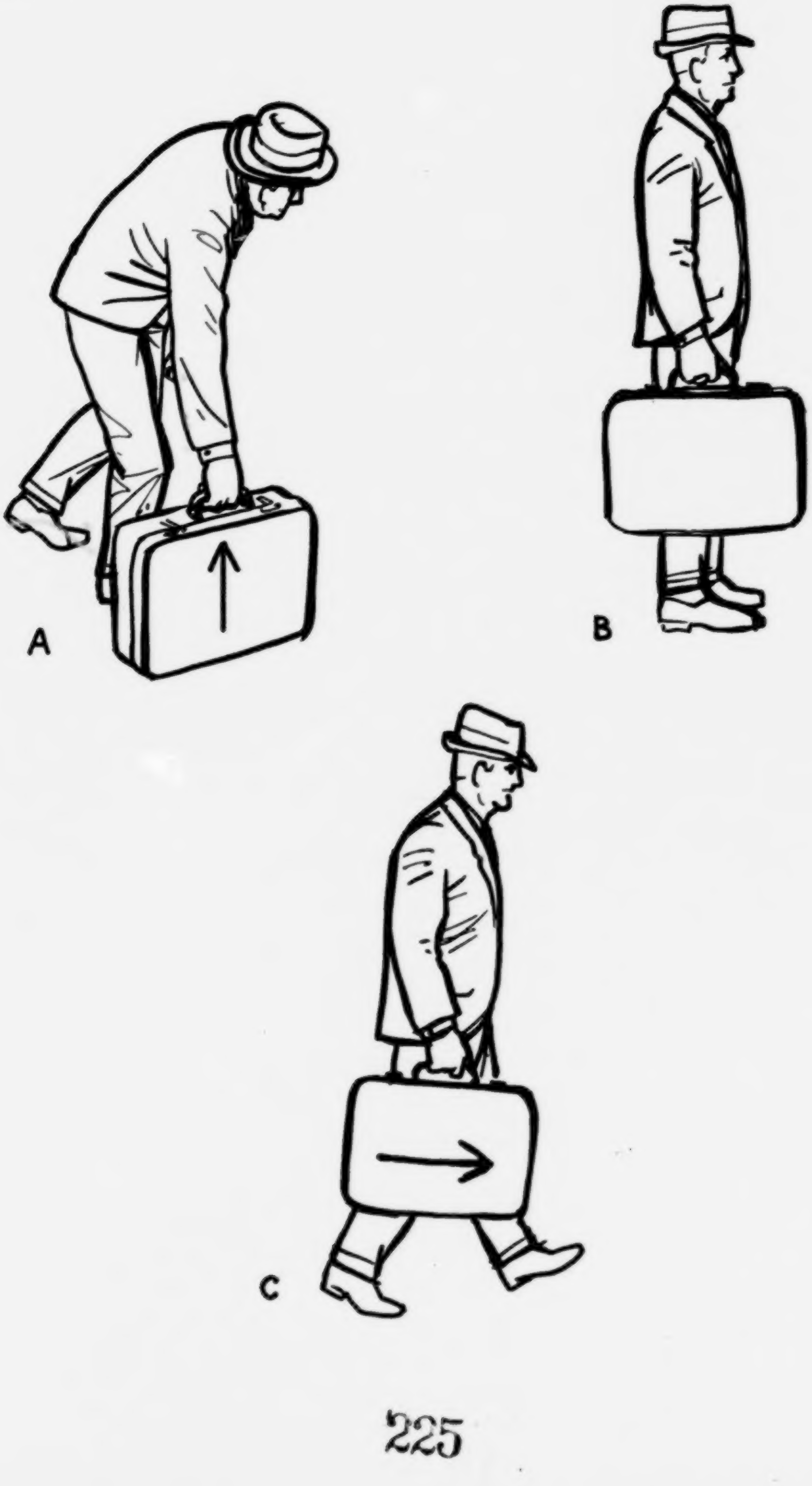
Physicists say work is accomplished when a force in the direction of motion acts to move a body through a distance.

Only one drawing illustrates work in this sense. Which one?

- ☐ Drawing A
- ☐ Drawing B
- ☐ Drawing C

Drawing C

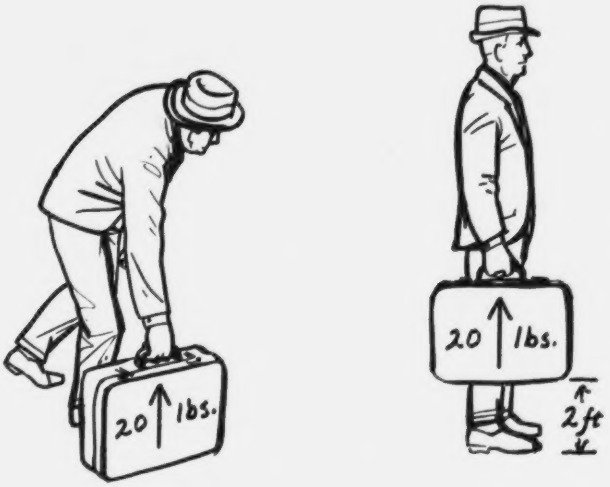
PANEL 3



12. REFER TO PANEL 3 Work is accomplished when a force, acting in the direction of motion, moves a body through a distance. In all three drawings in the panel, the force exerted is upward.	
In which drawing(s) is the body being moved through a distance? ☐ Drawing A ☐ Drawing B ☐ Drawing C	Drawing A Drawing C
In which drawing(s) is the force acting in the direction of motion? ☐ Drawing A ☐ Drawing B ☐ Drawing C	Drawing A Drawing C
In which drawing(s) is work, in the scientific sense, being accomplished? ☐ Drawing A ☐ Drawing B ☐ Drawing C	Drawing A Drawing C
13. In scientific usage, work is accomplished whenever: ☐ a body is in motion ☐ a force acts on a body, whether in motion or at rest ☐ a force in any direction acts on a body over a distance ☐ a force in the direction of motion acts on a body over a distance	. . . in the direction of . . .

14. Now that we have defined work, we can go on to see how it is measured. The amount of work done on an object is equal to the force acting on it multiplied by the distance over which the force acts. If a force of 10 lbs. acts to move a body 10 feet, the work done is: 10 feet x 10 pounds = __________ foot-pounds.	100
15. FOOTNOTE FRAME Work is calculated by multiplying distance (a length measurement) by force (a weight measurement). The result is a length-weight measurement. If distance is expressed in feet, and force in pounds, the work measure is expressed as foot-pounds. If distance is in centimeters, and force in grams, the work measure is expressed as gram-centimeters. Other work measures you may come across are: the erg: 980 ergs = 1 gram-centimeter the joule: 1 joule = 10,000,000 ergs Some of these terms will be used in this lesson, but you need not memorize them. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

16.


20 lbs.
20 lbs.
2 ft

Work is calculated by multiplying the force acting on a body by the distance the body moves in the direction of the force.

When an object is lifted at a steady rate, the force exerted must just balance the gravitational force pulling down. This force is just equal to the object's weight.

In the picture, the force exerted in lifting the suitcase is _____ pounds.	20
How many foot-pounds of work are done in lifting it? _____	40 ft.lbs.

17.	
What two quantities are multiplied to figure the amount of work done?	
☐ distance moved	
☐ distance moved in direction in which force acts	distance moved in . . .
☐ force acting on a body at rest or in motion	
☐ force acting to move a body through a distance	force acting to move a body . . .
18.	
F is a force acting to move a body through a distance.	
D is the distance moved in the direction of the force.	
The work done is calculated by:	
☐ F ÷ D ☐ F x D ☐ F + D ☐ F - D	F x D

19. An object weighing 20 grams is lifted 10 centimeters off the ground. How much work is done? ☐ 20 gram-centimeters ☐ 30 gram-centimeters ☐ 200 gram-centimeters ☐ none	200 gram-centimeters
An object weighing 5 grams is held 40 centimeters above the ground. How much work is done? ☐ 20 gram-centimeters ☐ 30 gram-centimeters ☐ 200 gram-centimeters ☐ none	none
20. Energy is measured in the same way as work, since energy is the ability to do work. Thus, if we say a quantity of energy is equal to 30 foot-pounds, we mean it is sufficient to move 30 pounds 1 foot, or to move 1 pound 30 feet, and so on. The same kind of measurement is used for all kinds of energy you have learned about in previous lessons: heat energy, electrical energy, mechanical energy, and so on. However, the calculation of energy quantities is simplest in dealing with mechanical energy -- which, as you may remember, is defined as: "the ordered movement of the molecules of a body moving from one place to another." In discussing the Principle of the Conservation of Energy, we will be talking mainly about mechanical energy. Keep in mind, however, that we use mechanical energy only as a convenient example of energy in general -- the same conclusions could be drawn for other kinds of energy, as well.	
NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

21.

Physicists distinguish between two kinds of mechanical energy:

a. the energy of a moving body

b. energy which a body has because of its position

One kind is called kinetic energy.

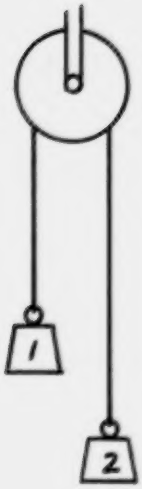
In a previous lesson, you learned about kinetic friction, the friction that acts on a moving body.

Using this earlier definition as a clue, you can tell that kinetic energy is the kind described:

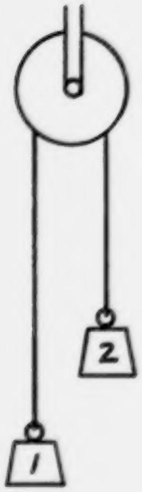
☐ in a. above
☐ in b. above

in a. above

PANEL 4



A.



B.

22.	
REFER TO PANEL 4	
The kind of energy a body has because of its position is called potential energy.	
When we do work on a body by raising it, we increase its potential energy, because we increase its ability to do work. For example, suppose we raise a weight, attach a string to it with another weight at the other end, and run the string over a pulley, as in Drawing A.	
Now we let the first weight fall, and the other weight is pulled up, as in Drawing B.	
In Drawing A, which is the weight whose potential energy has been increased?	
☐ Weight #1 ☐ Weight #2	Weight #1
In Drawing B, the increased potential energy has been used to do work. What work?	
☐ lowering Weight #1 ☐ raising Weight #2	raising Weight #2
In Drawing B, the potential energy of one weight has been transferred to the other. Which weight has lost potential energy? ______________	Weight #1
Which one has gained potential energy? ______________	Weight #2

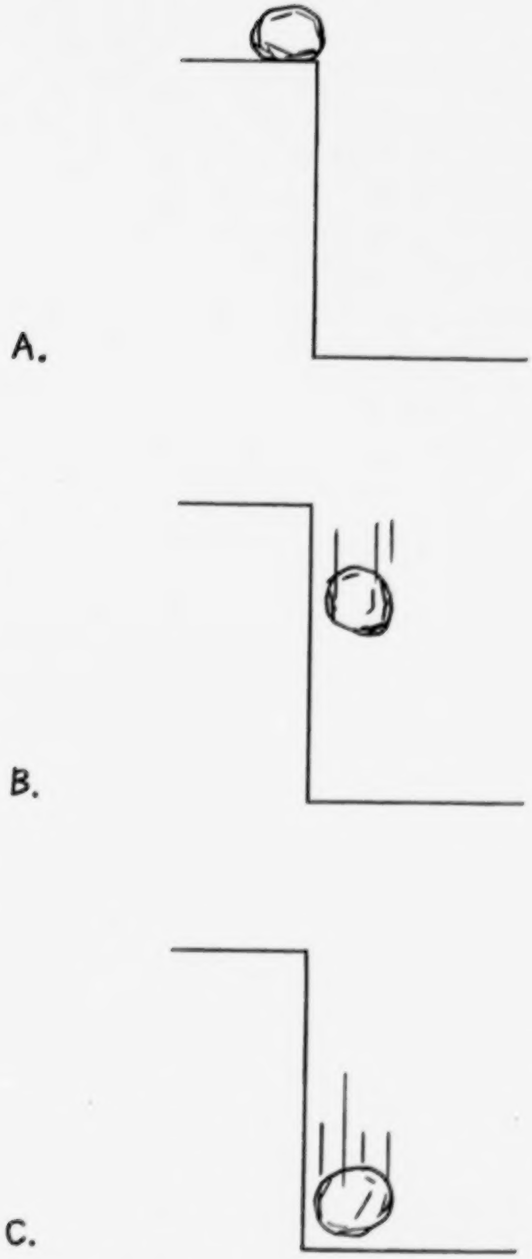
23. MATCH the terms and definitions: A. kinetic energy B. potential energy	
1. _____ energy due to a body's position	1. B
2. _____ energy of a moving body	2. A
3. _____ form of mechanical energy	3. A, B
24. FOOTNOTE FRAME Changes in potential energy are changes in a body's ability to do work, due to changes of position. Raising a weight is an example of changing a body's position in relation to a gravitational field. Similarly, changing the position of a charge in an electric field would change the ability of the charge to do work, and thus change its potential energy in relation to the electric field. As you can see, changes in potential energy can come about in different ways, not only through raising objects, or letting them fall. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
25. REFER TO PANEL 4 Weight #1 weighs 10 pounds. The point to which it was raised in Drawing A is 3 feet high. How many foot-pounds of work were done in raising it? __________	30
The increase in a body's potential energy is equal to the work done on the body. How much was Weight #1's potential energy increased? ______________	30 foot-pounds

26.	
REFER TO PANEL 4	
If Weight #1 and Weight #2 exchange positions, what happens to the potential energy of Weight #1 ?	
☐ decreases by 30 foot-pounds ☐ increases by 30 foot-pounds ☐ remains the same	decreases by 30 . . .
What happens to the potential energy of Weight #2 ?	
☐ decreases by 30 foot-pounds ☐ increases by 30 foot-pounds ☐ remains the same	increases by 30 . . .

27.	
REFER TO PANEL 4	
Together, these drawings illustrate a simple example of the Principle of the Conservation of Energy.	
Drawing A shows the result of putting in 30 foot-pounds of work, thus increasing the potential energy of Weight #1 by the same amount.	
In Drawing B, the situation has changed. The potential energy of Weight #1 has decreased by 30 foot-pounds.	
What happened to this energy?	
☐ it was destroyed ☐ it was transferred to Weight #2	it was transferred . . .
Similarly, the potential energy of Weight #2 has increased by 30 foot-pounds.	
Where did this energy come from?	
☐ it was created ☐ it was transferred from Weight #1	it was transferred . . .
In this example, energy is:	
☐ conserved ☐ created ☐ destroyed	conserved
Turn to back cover for Frame 28.	

28. REFER TO PANEL 5 (Page 22) Let us see what happens to potential energy when we let a lifted object fall freely. In Drawing A, we see a 5 pound rock which has been raised 5 feet above the ground. The work done in raising the rock increased its potential energy by the amount shown: _____ foot-pounds.	25
The kinetic energy of the rock in this drawing is 0. Why? ☐ A rock's kinetic energy is always 0. ☐ It is at rest. ☐ Work has been done on it.	It is at rest.
In B, the rock has begun to fall. As it accelerates because of the gravitational force acting on it, it gains kinetic energy. Where does this kinetic energy come from? ☐ It is created. ☐ It is converted from potential energy.	It is converted from . . . .

PANEL 5



29.

REFER TO PANEL 5

Notice the quantities of energy shown in Drawings A and B.

What happens to the rock's energy as it falls ?

(CHECK one column for each type of energy.)

	Decreases	Increases	Stays the same	Decreases	Increases	Stays the same
Kinetic energy	☐	☐	☐	☐	☒	☐
Potential energy	☐	☐	☐	☒	☐	☐
Total energy (kinetic plus potential)	☐	☐	☐	☐	☐	☒

In Drawing C, the rock is about to strike the ground. Its potential energy has decreased because it has changed its position in relation to the gravitational field.

What happened to the lost potential energy ?

____

It was converted to kinetic energy

(or equivalent response)

30. REFER TO PANEL 5 We assume here, as in previous examples, that there is no force of friction operating. (This, of course, is never true in real situations.) In this frictionless situation, the total energy of the rock remains the same throughout its fall. Its potential energy at any point in the fall is equal to its height above the ground times its weight -- that is, the amount of work you would do to raise it to that point.	
Suppose the rock were at the point in its fall where it was just two feet above the ground. What would its potential energy be? _____ foot-pounds.	10
Its total energy is still _____ foot-pounds.	25
What must its kinetic energy be? _____ foot-pounds.	15
31. By raising an object, we increase its: ☐ kinetic energy ☐ potential energy	potential energy
When we let the object fall freely, some of its: ☐ kinetic energy is converted to potential energy ☐ potential energy is converted to kinetic energy	potential energy is . . .

32.

When a falling object strikes the ground and stops, its kinetic energy decreases to zero.

Let us see what has happened to the lost energy.

If it strikes the ground hard enough, it may dislodge dirt and pebbles, and send them flying off. If this happens, some of the kinetic energy of the falling object has been:

- ☐ converted to potential energy
- ☐ destroyed
- ☐ transferred as kinetic energy to other objects

transferred as kinetic . . .

33.

Some of an object's kinetic energy may be transferred to other objects as it strikes the ground.

Some of it may also be converted to sound, another form of energy. But this still does not account for all of the "missing" energy.

We can tell what happens to the rest of it, if we make very careful measurements of the temperature of the falling object, and of the air and the ground around it, both before and after the object strikes the ground.

We would find very small, but definite, increases in these temperatures.

You can say, then, that part of the falling object's kinetic energy has been:

- ☐ converted to heat energy
- ☐ converted to potential energy
- ☐ destroyed

converted to heat energy

34. When a falling object strikes the ground, its kinetic energy decreases to zero. What happens to this energy? ☐ It is completely destroyed. ☐ It is converted to other forms of energy. ☐ Some of it is destroyed. ☐ Some of it is transferred to other objects.	It is converted to other . . . . Some of it is transferred . . . .
35. In the examples we have been considering, energy is: ☐ sometimes created ☐ sometimes destroyed ☐ neither created nor destroyed	neither created nor . . .
36. Scientists perform experiments where they study what happens to all kinds of energy under different conditions. The results of these experiments show that energy, like matter, is always conserved. What does this mean? ☐ An object's total energy always remains the same. ☐ Energy in one form is not converted to any other form. ☐ Energy is never created or destroyed.	Energy is never created or . . .

37. The Principle of the Conservation of Energy states that energy: ☐ can neither be created nor destroyed ☐ cannot be changed from one form to another ☐ cannot be transferred from one body to another	can neither be created . . .
38. FOOTNOTE FRAME Earlier in this lesson, we talked about the exception to the Principle of the Conservation of Matter -- nuclear reactions, where some matter is converted to energy. Of course, the same exception applies to the Principle of the Conservation of Energy, since energy is created when matter is destroyed. While nuclear reactions violate the principles of the conservation of matter and of energy, they do follow another combined principle, the Conservation of Matter and Energy. According to this principle, matter and energy are interchangeable, but the total quantity of both always stays the same. For most purposes, the two separate conservation principles are most useful; only in nuclear physics is it necessary to replace them with the combined conservation principle. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

39. REVIEW FRAME In a previous lesson, you learned about the two kinds of friction. Which one acts to prevent an object at rest from being set into motion? ☐ kinetic friction ☐ static friction What term is used for the friction which acts to slow down a moving body? ____________________	static friction kinetic friction
40. The faster a body is moving, the greater its kinetic energy. When kinetic friction slows down a moving body, the body's kinetic energy: ☐ decreases ☐ increases ☐ remains the same	decreases
41. The Principle of the Conservation of Energy tells us that the kinetic energy lost when a body is slowed down by friction: ☐ is destroyed ☐ may be converted to other forms of energy ☐ may be transferred to other objects	may be converted . . .

42. When friction slows down a moving body, the lost kinetic energy is converted to another form, some of which is transferred to other objects. Your own experience tells you what happens -- if you rub two objects together very rapidly, friction causes them to get warm. Indians took advantage of this fact to start campfires by rubbing dry sticks together. Friction converts kinetic energy into: ☐ electrical energy ☐ heat energy ☐ sound energy	heat energy
43. When friction slows down a moving object, what happens to the object's energy? ☐ It remains unchanged. ☐ Some of its kinetic energy is converted to heat energy. ☐ Some of its kinetic energy is transferred as kinetic energy to other objects. ☐ Some of its potential energy is converted to kinetic energy.	. . . converted to heat energy Time completed ______________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
WORK	Accomplished when a force in the direction of motion acts to move a body through a distance.
CALCULATION OF WORK	distance x force For example: When a 10 lb. weight is lifted 10 ft., the work done is 10 ft. x 10 lb., or 100 ft. - lbs.
ENERGY	ability to do work.
KINETIC ENERGY	energy of a moving body.
POTENTIAL ENERGY	energy possessed by a body because of its position.
VARIATIONS IN KINETIC AND POTENTIAL ENERGY	When a body is raised, its potential energy is increased. When the body falls, its potential energy is converted into kinetic energy. The potential energy is decreased, and the kinetic energy is increased. The total amount of energy remains constant.
TRANSFERENCE OR CONVERSION OF KINETIC ENERGY	The kinetic energy of a body may be transferred to another body, or it may be converted into heat or sound.
EFFECT OF FRICTION ON KINETIC ENERGY	Part of the kinetic energy is converted into heat energy.
PRINCIPLE OF THE CONSERVATION OF MATTER	Matter can be neither created nor destroyed. This rule applies to physical and chemical changes, but not to nuclear reactions, in which matter can be destroyed (and sometimes created).
PRINCIPLE OF THE CONSERVATION OF ENERGY	Energy can be neither created nor destroyed. This rule applies to physical and chemical changes, but not to nuclear reactions, in which energy can be created (and sometimes destroyed).

MASTERY TEST

NOTE NOTE NOTE NOTE NOTE

Skip two(2) pages to find question 1 on page 32.

Time started ________________.

1. A log weighing 10 pounds is burned to ashes. The ashes weigh 1/2 pound. The missing 9 1/2 pounds has been:

   a. ☐ changed to substances which are not visible

   b. ☐ converted to energy

   c. ☐ destroyed

2. The Principle of the Conservation of Matter implies:

   a. ☐ only that matter is never created

   b. ☐ only that matter is never destroyed

   c. ☐ that matter cannot be created or destroyed

   d. ☐ none of the above

3. In which of the following cases is work, in the scientific sense, accomplished?

   a. ☐ A body moves at constant velocity.

   b. ☐ An object is carried along at a steady rate three feet above the ground.

   c. ☐ An object is held three feet above the ground.

   d. ☐ An object is lifted three feet above the ground.

4. Changing a body's position in relation to a gravitational field:

   a. ☐ changes its kinetic energy

   b. ☐ changes its potential energy

   c. ☐ has no effect on its energy

5. To calculate the quantity of work done on a body, what information do you need?

   a. ☐ amount of force in any direction acting on the body

   b. ☐ amount of force, in the direction of motion, acting to move the body over a distance

   c. ☐ distance the body moves in any direction

   d. ☐ distance the body moves in the direction in which the force acts

   e. ☐ the body's velocity

6. When we let an object fall freely from a height:

   a. ☐ its kinetic energy decreases

   b. ☐ its kinetic energy increases

   c. ☐ its potential energy decreases

   d. ☐ its potential energy increases

7. A swiftly falling body hits the ground and stops. What happens to its kinetic energy?

   a. ☐ it becomes 0

   b. ☐ it increases

   c. ☐ it is converted partly to heat energy, partly to other forms of energy

   d. ☐ it remains unchanged

8. How much work is done in raising a 100-pound weight one foot?

   _____ foot-pounds.

9. What effect does friction have on a moving body?

   a. ☐ converts some of the body's heat energy to kinetic energy

   b. ☐ converts some of the body's kinetic energy to heat energy

   c. ☐ slows the body down

   d. ☐ speeds the body up

   e. ☐ no effect at all

10. According to the Principle of the Conservation of Energy, which of these statements is (are) true?

   a. ☐ Energy cannot be created.

   b. ☐ Energy cannot be destroyed.

   c. ☐ One form of energy cannot be converted to another form of energy.

   d. ☐ The energy of an object never changes.

Time completed ________________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-874

ED 070909

PM 431 - 67

ADVANCED
GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

SIMPLE MACHINES AND WORK
LEVEL: II
UNIT: 9
LESSON: 7

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

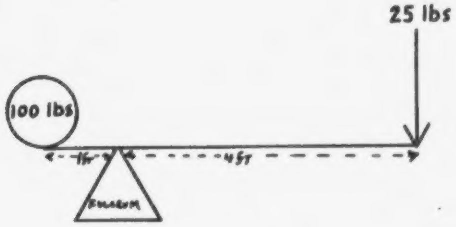
1. We live in an age of machines - machines of incredible complexity, powered by electricity, oil, gasoline, or even by nuclear energy. Because we think of machines in terms of these wonders of the modern world, we do not realize that machines have been making man's work easier for thousands of years. A machine is any device that makes a job easier by getting the greatest possible results from the energy it uses. In this lesson, you will learn about basic types of machines and how they make work easier. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
2. Machines do work. Energy, which is the ability to do work, cannot be created. Can a molecule do work without using energy? ☐ yes ☐ no	no
3. We put work (energy) into a machine in order to get work out. Assuming that the machine does not store up any energy, how much work (energy) can we expect to get out of a machine? ☐ as much as we put in ☐ less than we put in ☐ more than we put in	as much as we put in

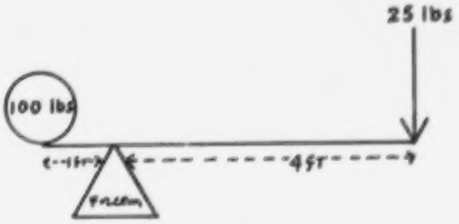
4. Machines make jobs easier, but they cannot violate the laws of nature. The work done by a machine - its work output - is: ☐ equal to the work (energy) put into it ☐ not equal to the work (energy) put into it	equal to the work . . .
5. FOOTNOTE FRAME In actuality, no machine ever has a work output equal to the work put into it. There are always losses due to friction -- that is, some of the energy put in is "wasted", instead of being used to do the work intended. For this reason, the actual work done by a machine is always less than the work done on it. In this section, we are discussing "ideal" conditions, where friction need not be considered. Later we will consider what happens under actual conditions. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
6. Ideally (ignoring friction), the work done by a machine: ☐ is always equal to the work done on it ☐ is always greater than the work done on it ☐ may be equal to or greater than the work done on it	is always equal to . . .

7. REVIEW FRAME Work is accomplished when a force in the direction of motion acts over a distance. How much work is done by a force, F, acting over a distance, d? ☐ F divided by d ☐ F minus d ☐ F plus d ☐ F times d	F times d
8. Work is equal to the force times the distance over which it acts. Suppose we want to keep the amount of work the same, while decreasing the force. What must we do to the distance? ☐ decrease it ☐ increase it ☐ leave it unchanged	increase it
9. We can accomplish the same amount of work with less force if we increase the distance over which the force acts. Suppose now that we want to decrease the distance over which a force acts and still do the same amount of work. What must we do to the force? ☐ decrease it ☐ increase it ☐ leave it unchanged	increase it

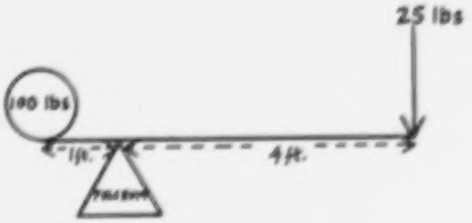
10. A given amount of work can be done with many different combinations of force and distance. For example, 30 foot-pounds of work may be done by a force of 3 pounds acting over a distance of 10 feet, or by a force of 10 pounds acting over a distance of 3 feet. How much force is needed, acting over a distance of 6 feet, to do 30 foot-pounds of work? __________	$\frac{30 \text{ ft.lbs}}{6 \text{ ft.}} = 5 \text{ lbs.}$
11. The work input to a machine cannot be less than its work output. But the applied input force can be less than the output force if the input distance is greater. Similarly, the input distance can be less than the output distance if the input force is greater. Work input and output will remain the same if: ☐ both the force and distance of the input are greater than the force and distance of the output ☐ both the force and distance of the input are less than the force and distance of the output ☐ the force of the input is less than the force of the output, while the distance of the input is greater than the distance of the output ☐ the distance of the input is less than the distance of the output, while the force of the input is greater than the force of the output	. . . is less than the force . . . . . . is less than . . .

12. Machines make work easier in one of two ways: 1. by increasing force while decreasing the distance over which it acts 2. by increasing the distance over which a force acts while decreasing the force Can a machine make work easier by multiplying both force and distance at the same time? ☐ yes ☐ no EXPLAIN your answer: ______________________	no because if both force and distance were multiplied, work output would be larger than work input, which is impossible (or equivalent response)
13. How can machines make work easier? ☐ by multiplying both force and distance at the same time ☐ by multiplying distance at the expense of force ☐ by multiplying force at the expense of distance ☐ by multiplying work	by multiplying distance . . . by multiplying force at . . .

14. Scientists call a device which multiplies force or distance in one step a simple machine. The most complicated machines in use today are actually combinations of simple machines. In the following frames, you will learn about the most common types of simple machines and some of their important characteristics. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
15.  The simple machine pictured here is a lever. It enables a man to lift a 100-pound rock at one end of the lever by exerting 25 pounds of force at the other end. In other words, it multiplies force four times. The number of times a simple machine multiplies force is called its mechanical advantage. The mechanical advantage of this lever is: ☐ 1/4 ☐ 1 ☐ 4	4

16.	
The mechanical advantage of a simple machine is the number of times it multiplies force.	
Suppose a lever allowed you to move a 200-pound rock by applying only 20 pounds of force. Its mechanical advantage would be _____.	10
17.	
	
The input force applied to a lever is called the effort force.	
The weight of the load to be lifted by a lever is called the resistance force.	
In the illustration, the effort force is _____ pounds.	25
The resistance force is _____ pounds.	100

18.



The point on which a lever rests is called the fulcrum.

The position of the fulcrum determines the distances over which the input and output forces act.

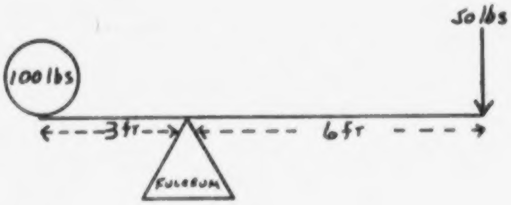
The distance from the fulcrum to the point where the effort force is applied is called the effort distance.

The distance from the fulcrum to the resistance force (the load) is called the resistance distance.

In the illustration, what is the effort distance?
_____ ft. 4

What is the resistance distance? _____ ft. 1

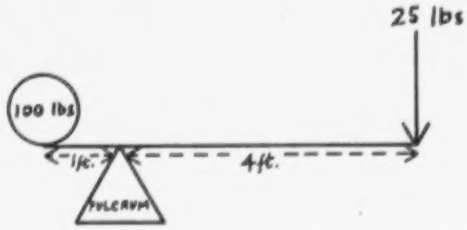
19.


50 lbs
100 lbs
3 ft
6 ft
FULCRUM

For the lever shown:

the effort force is _____ pounds	50
the resistance force is _____ pounds	100
the effort distance is _____ feet	6
the resistance distance is _____ feet	3

20.



We found the mechanical advantage of this lever, you will remember, by noting that it multiplied the effort force four times.

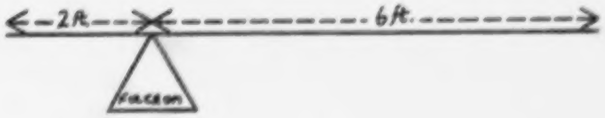
We can predict ahead of time how many times the effort force will be multiplied by comparing the effort distance and resistance distance.

The mechanical advantage of a simple machine, such as lever, is equal to:

☐ effort distance divided by resistance distance
☐ resistance distance divided by effort distance

effort distance divided . . .

21.



The mechanical advantage of a simple machine is equal to the effort distance divided by the resistance distance.

What is the mechanical advantage of this lever?

_____

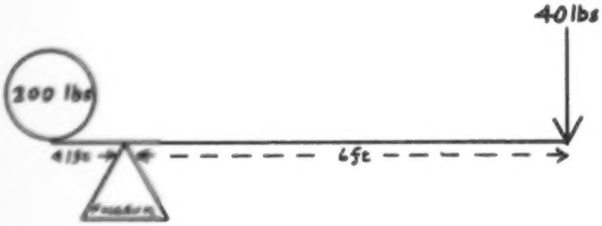
3

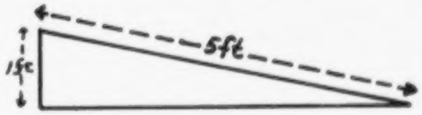
22.

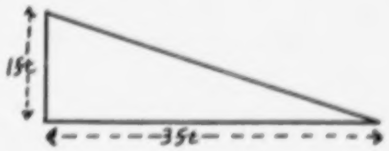
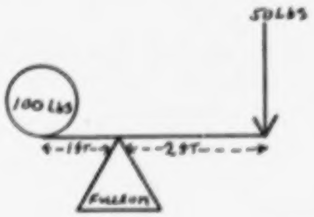
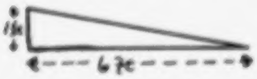
Ideally (ignoring friction), the mechanical advantage of a simple machine is equal to:

☐ effort distance divided by resistance distance
☐ effort distance minus resistance distance
☐ resistance distance divided by effort distance
☐ resistance distance times effort distance

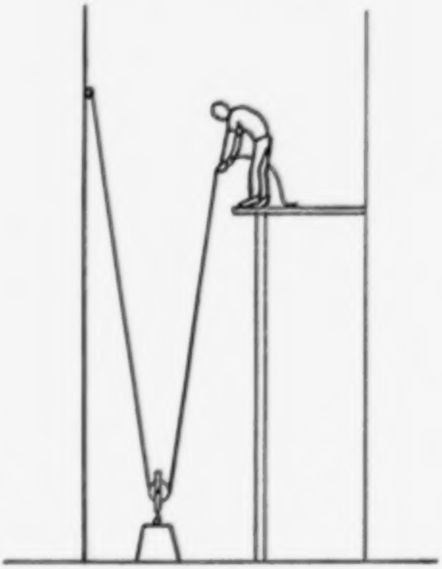
effort distance divided . . .

23. In any real situation, the force of friction operates to "steal" energy. For this reason, the work output of a machine is never quite equal to the work input. When we divide effort distance by resistance distance, we find the ideal mechanical advantage of a machine. It is called ideal because it ignores the force of friction. To find the actual mechanical advantage of a machine, we compare effort force with resistance force. Suppose we exert 30 pounds of force on a lever to lift a 105-pound load. The actual mechanical advantage of the lever is the number of times it multiplies the effort force - in this case, _____ times.	3.5 or 3 1/2
24.  What is the ideal mechanical advantage of this lever? (COMPARE distances) _____	6
What is its actual mechanical advantage? (COMPARE forces) _____	5
Friction always acts to make work output less than work input, so the actual mechanical advantage of a machine is always: ☐ equal to its ideal mechanical advantage ☐ less than its ideal mechanical advantage ☐ more than its ideal mechanical advantage	less than its ideal . . .

25. How are ideal mechanical advantage and actual mechanical advantage related? ☐ Actual mechanical advantage is always greater than ideal mechanical advantage. ☐ Ideal mechanical advantage is always greater than actual mechanical advantage. ☐ They are always equal.	Ideal mechanical . . .
26.  It may surprise you to know that a ramp is a kind of simple machine. Physicists call it an "inclined plane" because it consists of a flat surface (a plane) set at an angle (inclined). If you stop to think about it, you will realize that it is easier to pull a heavy load up a ramp than it is to lift the load up directly. The effort distance for an inclined plane is the length of the slope. The resistance distance is the height of the upper end. What is the ideal mechanical advantage of the ramp shown here? _____ Ignoring friction, how heavy a load could you pull up with an effort force of 20 pounds? (HINT: multiply) _____ pounds	5 100

27.	
	
The mechanical advantage of this inclined plane is ______.	3
Ideally (ignoring friction), how much effort force would you need to pull a 90-pound load to the top? (HINT: divide) ______ pounds	30
28.	
 50 LBS 100 LBS 1 FT 2 FT Fulcrum 	
What is the mechanical advantage of each of these simple machines?	
A. ______	2
B. ______	6

29.



An arrangement of ropes and pulleys, like this one, is another type of simple machine.

The resistance distance is the height to which the weight is to be raised.

The effort distance is the length of the rope supporting the weight

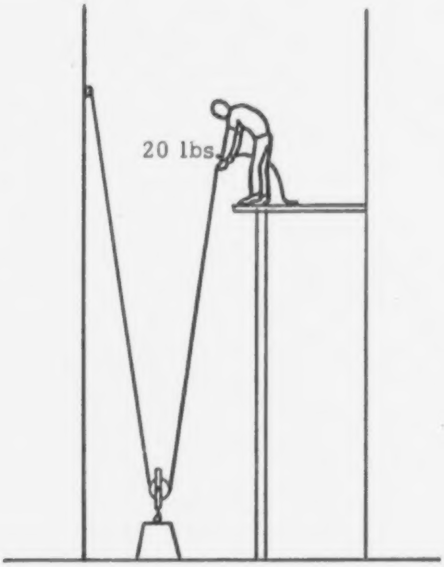
In a single pulley arrangement like this, the rope is twice as long as the height.

Its mechanical advantage, then, is:

☐ 1/2
☐ 1
☐ 2
☐ none

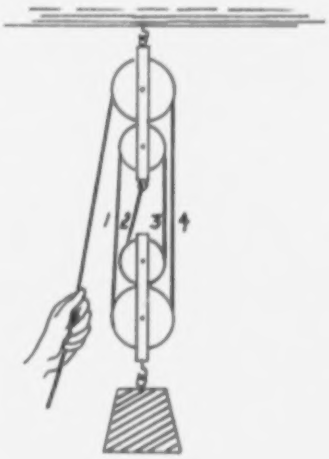
2

30.



The ideal mechanical advantage of this simple machine is 2.	
Assuming a "frictionless" pulley, how heavy a weight could be raised with the effort force shown? _____ pounds	40
Pulling the rope 2 feet will raise the weight how many feet? _____	1 foot

31.



You could calculate the ideal mechanical advantage of this pulley system by measuring the total length of the rope supporting the weight, then dividing by the height.

An easier method, which gives the same results, is simply to count the number of ropes supporting the weight, as we have done in the drawing.

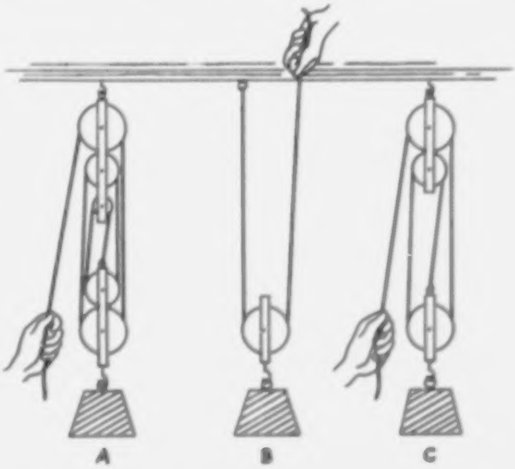
The ideal mechanical advantage of this pulley system is 4.

The ideal mechanical advantage of a system of pulleys is:

- ☐ equal to the number of supporting ropes
- ☐ greater than the number of supporting ropes
- ☐ less than the number of supporting ropes

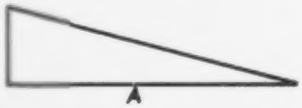
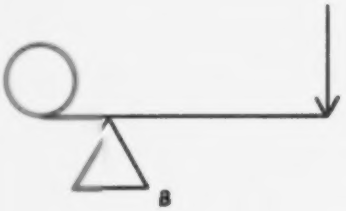
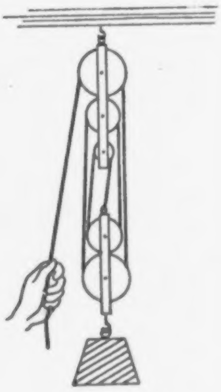
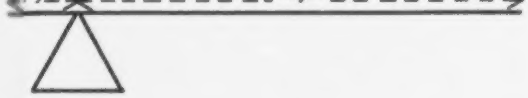
equal to the number of . . .

32.

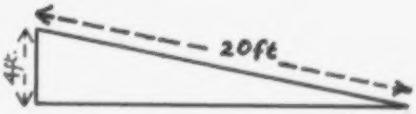


What is the ideal mechanical advantage of each of these pulley systems?

A _____	5
B _____	2
C _____	3
Ideally, how much effort force would be needed to raise a 50-pound weight with the arrangement of pulleys shown in A? _____ pounds.	10

33.  A  B  C Which of the simple machines pictured above has an ideal mechanical advantage of: (GIVE LETTERS)	
3 ____	B
4 ____	A
5 ____	C
34.  Ignoring friction, how much effort force would be required to lift a 300-pound rock with the lever shown? ____ pounds.	50

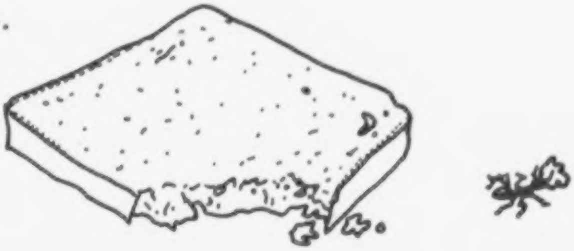
35.



Ignoring friction, how heavy a load could be pulled up this ramp with an effort force of 20 pounds?
_____ pounds.

100

36.



This hard-working ant is busy carrying a slice of bread, a crumb at a time, to his anthill. Given enough time, he will have all the bread where he wants it.

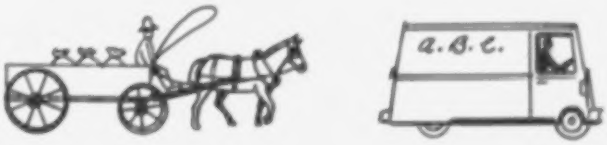
You, of course, could do the job in one trip.

You and the ant are capable of doing the same amount of work, but you do it much faster. We say that you are more powerful than the ant.

Power is a measurement of work that takes time into account. It is the subject of this last section.

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

37.  You can haul a 200-pound load ten miles with the horse and wagon or with the truck. The truck gets the job done much faster, because it has more power. Power is the: ☐ ability to do work ☐ rate at which work is done	rate at which work is done
38. Since power is the rate at which work is done, it is calculated by dividing the amount of work by the length of time. Any units of work and time can be used. For example, if a machine can do 100 foot-pounds of work in 2 hours, we can express its power as: $\frac{\text{100 foot-pounds}}{\text{2 hours}} = \text{50 foot-pounds per hour}$ Which of the following are measures of power? (HINT: A joule is a work measure, equal to about 3/4 of a foot-pound.) ☐ 10 feet per second ☐ 25 foot-pounds per minute ☐ 30 gram-centimeters ☐ 50 joules per second	25 foot-pounds per minute 50 joules per second

39. Power is: ☐ number of times a machine multiplies effort force ☐ rate of change in velocity ☐ rate at which work is done ☐ relationship between work input and work output of a machine	rate at which work is done
40. To calculate power, multiply force by the distance through which the force acts, then divide by time. For example, the power needed to move 20 pounds through a distance of 20 feet, in 5 minutes, is: $\frac{\text{20 pounds x 20 feet}}{\text{5 minutes}} = \frac{\text{400 foot-pounds}}{\text{5 minutes}} =$ 80 foot-pounds per minute CALCULATE the power required to move 40 pounds 10 feet in 2 minutes:	$\frac{\text{10 feet x 40 pounds}}{\text{2 minutes}} =$ 200 foot-pounds per minute

41.

FOOTNOTE FRAME

While any combination of weight, length and time units can be used to measure power, some standard power units have been devised.

Power units you may come across are:

Horsepower (abbreviated hp):

1 hp equals 550 foot-pounds per second

Watt:

1 watt equals 1 joule per second

Kilowatt (abbreviated kw):

1 kw equals 1,000 watts

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

42.

A. moving 100 pounds 3 feet in 5 seconds

$$\frac{(100 \text{ pounds} \times 3 \text{ feet})}{5 \text{ seconds}}$$

B. moving 50 pounds 6 feet in 10 seconds

$$\frac{(50 \text{ pounds} \times 6 \text{ feet})}{10 \text{ seconds}}$$

How much power is required for each job?

A. _____ foot-pounds per second	60
B. _____ foot-pounds per second	30
Which job required more power? _____	A

43. Which requires more power? ☐ moving a 50-pound weight 10 feet in 2 minutes ☐ moving a 100-pound weight 5 feet in 1 minute ☐ no difference	moving a 100-pound weight . . . Time completed ________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
RELATIONSHIP BETWEEN WORK DONE ON A MACHINE AND WORK DONE BY THE MACHINE	
IDEAL (ignoring friction)	The work done by a machine is equal to the work done on it.
ACTUAL (taking friction into account)	The work done by a machine is less than the work done on it. Some work is wasted against friction.
HOW MACHINES MAKE WORK EASIER	by multiplying distance at the expense of force
	EXAMPLE: If a man pushes one end of a lever down with a force of 20 lbs. through a distance of 2 ft., he can lift a 10 lb. weight at the other end through a distance of 4 ft. Less force is lifted through a greater distance.
	by multiplying force at the expense of distance
	EXAMPLE: If a man pushes one end of a lever down with a force of 20 lbs. through a distance of 2 ft., he can lift a 40 lb. weight at the other end through a distance of 1 ft. The distance is less, but the force is greater.
MECHANICAL ADVANTAGE	The number of times that a machine multiplies force or distance.
EFFORT FORCE	input force
LEVER	the force applied to one end of the lever
INCLINED PLANE	the force applied to the body pushed up the plane.
PULLEY	the force applied to one end of the rope.
RESISTANCE FORCE	output force
LEVER	the weight of the body lifted by the lever.
INCLINED PLANE	the weight of the body pushed up the plane.
PULLEY	the weight of the body lifted by the rope.
FULCRUM	point on which a lever rests.

WORD	DEFINITION
EFFORT DISTANCE	
LEVER	distance from the fulcrum to the point where the effort force is applied.
INCLINED PLANE	length of the plane from ground to the top.
PULLEY	length of the rope supporting the weight.
RESISTANCE DISTANCE	
LEVER	distance from the fulcrum to the point where the resistance force is lifted.
INCLINED PLANE	height of the upper end.
PULLEY	height through which weight is to be lifted.
CALCULATION OF MECHANICAL ADVANTAGE	
IDEAL (ignoring friction)	effort distance divided by resistance distance. EXAMPLE: If the effort distance of a lever is 6 ft., and the resistance distance is 1 ft., then the mechanical advantage is 6.
ACTUAL (taking friction into account)	effort force divided by resistance force. EXAMPLE: If the effort force applied to a lever is 20 lbs. and the weight of the body lifted is 10 lbs., then the actual mechanical advantage is 2. Because of friction, the actual mechanical advantage of a machine is always less than its ideal mechanical advantage.
CALCULATION OF LOAD THAT CAN BE MOVED BY SIMPLE MACHINE	effort force multiplied by mechanical advantage. EXAMPLE: If a body is pushed up an inclined plane with an effort force of 20 lbs., and the mechanical advantage of the plane is 5, then the body can weigh up to 100 lbs.

WORD	DEFINITION
POWER	rate at which work is done.
CALCULATION OF POWER	Work (distance through which force acts) divided by time. EXAMPLE: The power required to move 40 pounds through 10 feet in 2 minutes is (40 x 10) divided by 2, or 200 foot-pounds per minute.

MASTERY TEST

Time started ______________

1. Machines make work easier because:

   a. ☐ their work output is greater than their work input

   b. ☐ they can multiply a force without changing the distance over which it acts

   c. ☐ they can multiply the distance over which a force acts without changing the force

   d. ☐ they can multiply force at the expense of distance or distance at the expense of force

2. The ideal mechanical advantage of a simple machine is calculated from the effort distance and the resistance distance. How would you make the calculation?

   ____

3. Which measure ignores friction?

   a. ☐ actual mechanical advantage

   b. ☐ ideal mechanical advantage

   c. ☐ both of the above

   d. ☐ neither of the above

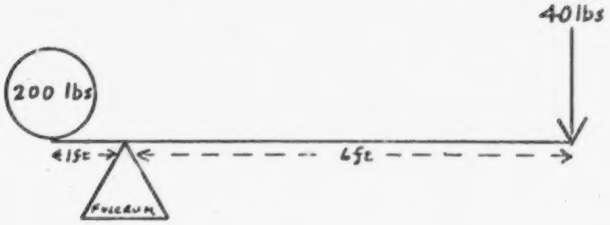
4. Which one is larger?

   a. ☐ actual mechanical advantage

   b. ☐ ideal mechanical advantage

   c. ☐ no difference

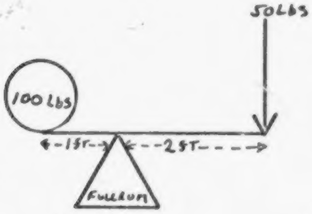
5.


40 lbs
200 lbs
1ft
6ft
Fulcrum

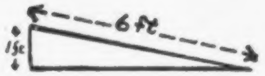
What is the ideal mechanical advantage of this lever? _____

Ignoring friction, how heavy a load could you lift with an effort force of 10 pounds? _____ pounds.

6.


50Lbs
100 Lbs
1ft
2ft
Fulcrum

A



B

What is the ideal mechanical advantage of each simple machine?

A. _____

B. _____

7. Which of the following is a measure of power?

a. ☐ 30 feet per second

b. ☐ 50 foot-pounds per hour

c. ☐ 100 gram-centimeters

8. How much power is needed to move a 1000-pound load 5 feet in 10 seconds? _____ foot-pounds per second

Time completed _______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-875

ED 070909

PM 431 - 68

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

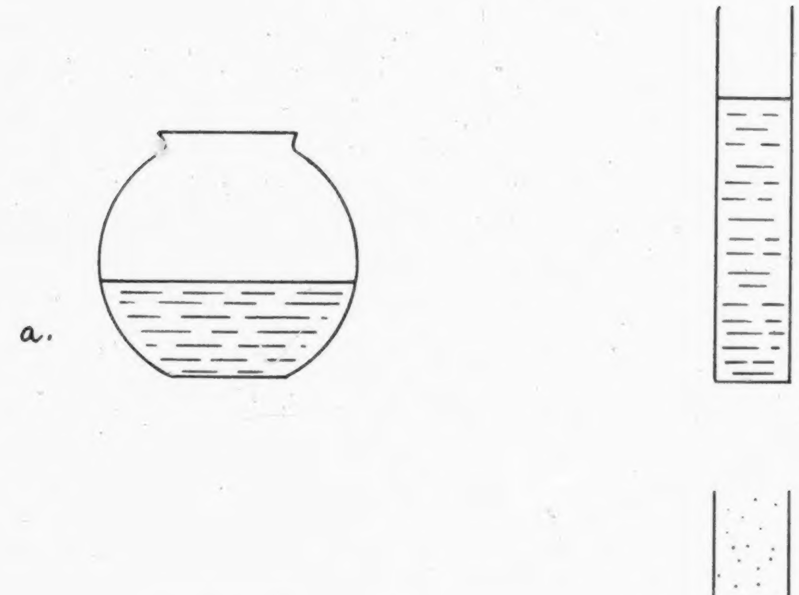
GAS LAWS
LEVEL: II
UNIT: 9
LESSON: 8

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

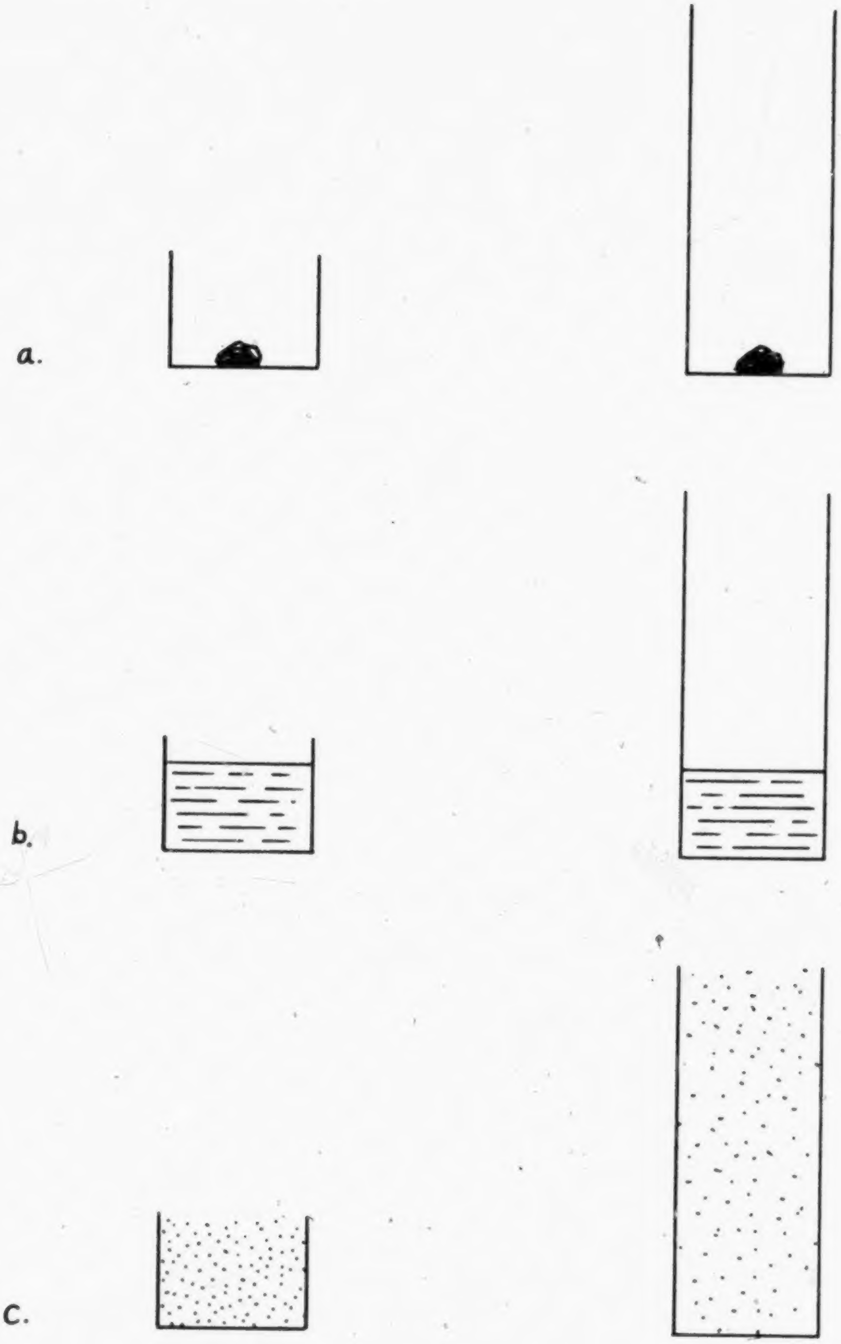
1. Think of a car and a bicycle. Which body occupies more space? ☐ the bicycle ☐ the car Think of a balloon filled with air and a rock the same size. Which body is made up of more matter? ☐ the balloon ☐ the rock	the car the rock
2. The amount of space that a body occupies is called its volume, and the amount of matter that makes it up is called its mass. Suppose there is a block of aluminum twice the size of a block of steel. The block of aluminum occupies more space, but the steel has more matter, because the matter in the steel is more compact. Which body has the greater volume? ☐ the block of aluminum ☐ the block of steel Which body has the greater mass? ☐ the block of aluminum ☐ the block of steel	the block of aluminum the block of steel

PANEL 1



3. The volume of a body is: ☐ the amount of matter that makes it up ☐ the amount of space that it occupies	the amount of space . . .
The mass of a body is: ☐ the amount of matter that makes it up ☐ the amount of space that it occupies	the amount of matter . . .
4. In a previous lesson, you learned that there are three different kinds of matter: solids, liquids and gases. When we compare these three kinds of matter, we see that they have different properties. REFER TO PANEL 1 Each picture on the left of PANEL 1 shows a liquid, a gas or a solid in a fish bowl. The same substances are shown on the right side of the PANEL in a different container, a tall tube. Notice the shape of the solid. You can see that the shape of the solid is the same in the tube as it is in the bowl. Liquids and gases also have shapes, but their shapes can change. For example, when the liquid is in the bowl, it has a round shape, but when it is in the tube, it has a long, thin shape. The same applies to the gas. Thus, a solid has: ☐ the shape of the container that holds it ☐ a shape of its own	a shape of its own
A liquid has: ☐ the shape of the container that holds it ☐ a shape of its own	the shape of the container . . .
A gas has: ☐ the shape of the container that holds it ☐ a shape of its own	the shape of the container . . .

PANEL 2



5.

REFER TO PANEL 2

As in PANEL 1, each picture on the left of PANEL 2 shows a solid, a liquid and a gas in a container, but this time the container is a small box, instead of a fish bowl. On the right side of the PANEL, each substance is shown in a larger box, one that can hold much more.

Notice the volume of the solid. You can see that the volume of the solid in the larger box is the same as its volume in the smaller box. This is true also of the liquid, which rises to the same level in both boxes.

When the gas is put into the larger box, however, it expands, and its volume becomes the same as that of the box.

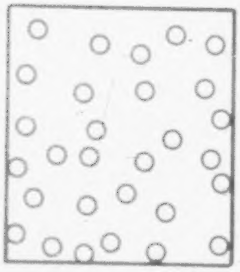
Thus, a solid has: ☐ a volume of its own ☐ the volume of the container that holds it	a volume of its own
A liquid has: ☐ a volume of its own ☐ the volume of the container that holds it	a volume of its own
A gas has: ☐ a volume of its own ☐ the volume of the container that holds it	the volume of the container . . .

6. MATCH the columns below to compare a solid, a liquid and a gas: A. has a shape of its own B. has the shape of its container C. has a volume of its own D. has the volume of its container 1. _____ gas 2. _____ liquid 3. _____ solid	B, D B, C A, C
7. A substance that has the shape of the container that holds it is called a fluid. Which of the following substances are fluids? ☐ gases ☐ liquids ☐ solids	gases liquids
8. A fluid is a substance that has: ☐ the shape of the container that holds it ☐ a shape of its own	the shape of the container . . .

9. In a previous lesson, you learned that kinetic energy is the energy associated with the movement of a body. You also learned that the molecules of a gas are constantly in motion. Thus, the molecules of a gas: ☐ do not have kinetic energy ☐ have kinetic energy	have kinetic energy
10. Since the kinetic energy of a body depends on its motion, you can guess that, the greater the speed of the body: ☐ the less its kinetic energy ☐ the more its kinetic energy	the more . . .
11. Not all the molecules in a gas move at the same speed. Some move faster, some slower. Thus, the kinetic energies of different gas molecules are: ☐ different ☐ the same	different

12.	
Just as molecules have different kinetic energies, people have different weights. Some people weigh 110 lbs., others weigh 180 lbs. If we were to add the weights of many people and then divide the sum by the number of people, we would obtain the average weight of the people in the group, which might be about 150 lbs. The average weight would not tell us the weight of each person in the group, but it would tell us the weight of a person who was typical of the group. Similarly, if we were to add the kinetic energies of all the molecules in a gas and then divide the sum by the number of molecules, we would obtain the average kinetic energy of the molecules in the gas.	
You can see that some molecules in the gas would have:	
☐ the average kinetic energy	the average . . .
☐ less than the average kinetic energy	less than the average . . .
☐ more than the average kinetic energy	more than the average . . .
A typical molecule would have:	
☐ the average kinetic energy	the average kinetic energy
☐ less than the average kinetic energy	
☐ more than the average kinetic energy	
13.	
The average kinetic energy of a gas is the kinetic energy of:	
☐ each molecule in the gas	
☐ a typical molecule in the gas	a typical molecule . . .

14.



The picture above shows a gas in a box-like container. Individual molecules of the gas are represented by small circles.

The picture shows that the molecules of the gas:

☐ collide with the walls of the container
☐ do not collide with the walls of the container

collide with the walls . . .

15.

When a gas, such as air or helium, or a liquid, such as water, is put into a balloon, the balloon fills out. This happens because the gas or liquid "pushes" against the wall of the balloon.

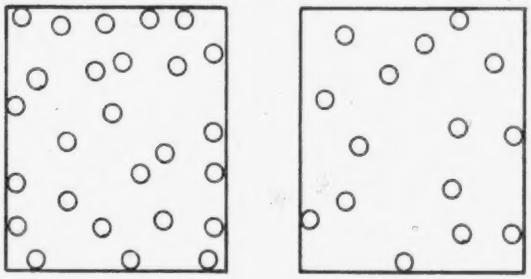
Similarly, the gas feeding an oven, or the water feeding a shower, pushes against the wall of the pipe that carries it.

The push of a fluid against the walls of its container is called pressure.

Pressure is exerted on the walls of a container by:

☐ a gas
☐ a liquid

a gas
a liquid

16.	
CHECK the properties of a gas listed below:	
☐ it exerts pressure on the walls of the container	it exerts pressure on the . . .
☐ its molecules collide with the walls of the container	its molecules collide with . . .
☐ its molecules have an average kinetic energy	its molecules have an . . .
☐ none of the above	
17.	
 Gas 1 Gas 2	
The pictures above show two containers, each containing a different gas.	
Compare the number of molecules that are colliding with the container walls in each case. You can see that there is a greater number of collisions in the case of:	
☐ Gas 1 ☐ Gas 2	Gas 1
The speed of the gas molecules cannot be shown, but suppose that the speed were greater in the case of Gas 2. This would mean that the average kinetic energy would be greater in the case of:	
☐ Gas 1 ☐ Gas 2	Gas 2

18.	
The pressure exerted by a gas on the walls of its container is caused by the collision of the gas molecules with the walls.	
The degree of pressure depends on the number of molecules that collide with the walls and on the average kinetic energy of the molecules.	
You can guess that the pressure increases when the number of molecules that collide with the walls:	
☐ decreases	
☐ increases	increases
and that the pressure also increases when the average kinetic energy:	
☐ decreases	
☐ increases	increases
What would cause a decrease in pressure?	
☐ a decrease in the number of molecules that collide with the walls	a decrease in the number . . .
☐ a decrease in the average kinetic energy	a decrease in the average . . .
☐ an increase in the number of molecules that collide with the walls	
☐ an increase in the average kinetic energy	

19.

The degree of pressure depends on the number of molecules that collide with the walls and on the average kinetic energy of the molecules. If the number of molecules that collide with the walls is increased, the pressure will increase.

Suppose, however, there was an increase in the number of gas molecules that collide with the walls of a container, but at the same time there was a decrease in the average kinetic energy of the molecules. The pressure, which is the net effect of both, might remain the same.

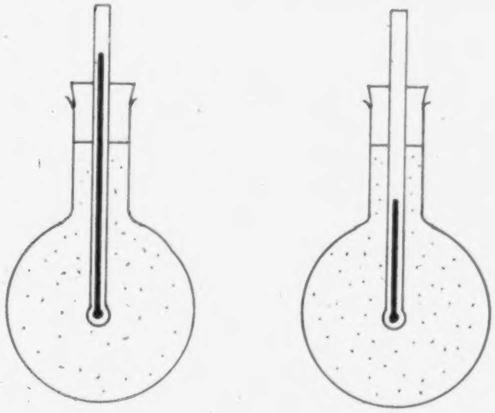
Thus, if we want to see what effect a change in the number of collisions will have on the pressure, we must keep the average kinetic energy the same (constant).

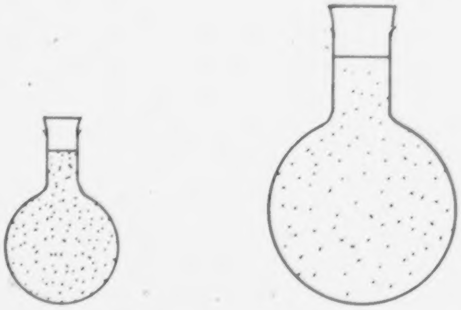
If we want to see what effect a change in the average kinetic energy has on the pressure, we must keep:

- ☐ the average kinetic energy constant
- ☐ the number of molecules that collide with the container walls constant

the number of molecules. . .

20.	
If the number of gas molecules that collide with the walls of a container is constant, an increase in the average kinetic energy of the molecules:	
☐ decreases the pressure exerted by the gas	
☐ increases the pressure exerted by the gas	increases the . . .
☐ neither increases nor decreases the pressure exerted by the gas	
If the average kinetic energy of gas molecules is constant, an increase in the number of molecules that hit the walls of a container:	
☐ decreases the pressure exerted by the gas	
☐ increases the pressure exerted by the gas	increases the. . .
☐ neither increases nor decreases the pressure exerted by the gas	

21.	
The degree of pressure exerted by a gas on the walls of its container depends on:	
☐ the kinetic energy of the gas molecules	the kinetic energy . . .
☐ the number of gas molecules that collide with the walls of the container	the number of . . .
☐ neither of the above	
22. 	
The pictures above show two containers, each with a different gas. Though it can't be shown, the average kinetic energy of Gas 1 is greater than that of Gas 2.	
A thermometer has been inserted into each container and shows the temperature of each gas. Which gas has the higher temperature?	
☐ Gas 1 ☐ Gas 2	Gas 1
This illustration shows that, the greater the average kinetic energy of a gas:	
☐ the higher its temperature ☐ the lower its temperature	the higher its temperature

23. The temperature of a gas: ☐ does not measure the average kinetic energy of its molecules ☐ measures the average kinetic energy of its molecules	measures the average . . .
24.  The pictures above show two containers. The one on the right is much bigger than the one on the left. Suppose there were a gas in the container on the left and that it were transferred to the container on the right. Because the second container is much bigger, the gas molecules would not be as crowded and as a result, they would not collide as frequently with the walls. Thus, the number of molecules that collide with the walls of a container decreases when the volume of the container: ☐ decreases ☐ increases ☐ remains the same	increases
The number of molecules that collide with the walls of a container will increase when the volume of the container: ☐ decreases ☐ increases ☐ remains the same	decreases

25. As you know, when a gas, or any substance, is heated, its temperature rises, and when it is cooled, its temperature falls. Since temperature is an indication of the kinetic energy of the molecules of a substance, you can see that the average kinetic energy of a gas decreases when the gas is: ☐ cooled ☐ heated	cooled
and that the average kinetic energy increases when the gas is: ☐ cooled ☐ heated	heated
26. A decrease in the volume of the container that holds a gas causes the number of molecules that hit the walls of the container to: ☐ decrease ☐ increase ☐ neither increase nor decrease	increase
The addition of heat to a gas causes the average kinetic energy of the gas molecules to: ☐ decrease ☐ increase ☐ neither increase nor decrease	increase
As an indication of an increase in average kinetic energy, the temperature of the gas: ☐ falls ☐ rises ☐ remains the same	rises

27.	
A sealed container of gas is heated with a blowtorch. Since the pressure of a gas depends on its average kinetic energy, you can see that an increase in the temperature of the gas would cause the pressure to: ☐ decrease ☐ increase ☐ remain the same	increase
The pressure of a gas also depends on the number of molecules that collide with the walls of the container. Thus, if we keep the temperature the same an increase in the volume of the container would cause the pressure to: ☐ decrease ☐ increase ☐ remain the same	decrease
28.	
If the temperature of a gas is constant, a decrease in the volume of a container that holds a gas causes the pressure exerted by the gas to: ☐ decrease ☐ increase ☐ neither increase nor decrease	increase
If the volume of a gas is constant, an increase in the temperature of a gas causes the pressure exerted by the gas to: ☐ decrease ☐ increase ☐ neither increase nor decrease	increase

29. If the temperature of a gas is constant, an increase in the volume of a container that holds it causes the pressure exerted by the gas to: ☐ decrease ☐ increase ☐ neither increase nor decrease	decrease
If the volume of a gas is constant, a decrease in its temperature causes the pressure exerted by the gas to: ☐ decrease ☐ increase ☐ neither increase nor decrease	decrease
30. If we do not change the temperature of a gas, we know: 1. a decrease in its volume will increase its pressure. 2. an increase in its volume will decrease its pressure. We also know, that if we do not change the volume of a gas: 1. a decrease in its temperature will decrease its pressure. 2. an increase in its temperature will increase its pressure. However, if we change both the volume and temperature of a gas, we must take a look at the effect of both changes in order to predict how the pressure will change.	
NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

31. Suppose we decrease the volume of a gas and at the same time increase its temperature. The pressure of the gas will: ☐ decrease ☐ increase ☐ either increase or decrease or remain the same	increase
32. Suppose we increase the volume of a gas and at the same time decrease the temperature. The pressure of the gas will: ☐ decrease ☐ increase ☐ either increase or decrease or remain the same	decrease
33. Suppose we increased the volume of a gas at the same time that we raised its temperature. The increase in volume would: ☐ decrease the pressure ☐ increase the pressure and the increase in temperature would: ☐ decrease the pressure ☐ increase the pressure Consequently, the pressure of the gas would: ☐ decrease ☐ increase ☐ either increase or decrease or remain the same	decrease the pressure increase the pressure either increase . . .

34. A gas can be heated without changing the pressure, if, at the same time that the temperature rises, the volume of the container: ☐ decreases ☐ increases ☐ neither increases nor decreases	increases
A gas can be cooled without changing the pressure, if, at the same time that the temperature falls, the volume of the container: ☐ decreases ☐ increases ☐ neither increases nor decreases	decreases
35. CHECK the appropriate boxes below to indicate how the pressure, the temperature and the volume of a gas are related to one another:	
☐ at constant temperature, a decrease in the volume of a gas causes an increase in the pressure	at constant temperature, a . . .
☐ at constant temperature, an increase in the volume of a gas causes a decrease in the pressure	at constant temperature, an . . .
☐ at constant volume, a decrease in the temperature of a gas causes a decrease in the pressure	at constant volume, a . . .
☐ at constant volume, an increase in the temperature of a gas causes an increase in the pressure	at constant volume, an . . .
☐ constant pressure can be maintained when a gas is cooled by decreasing the volume	constant pressure can be . . .
☐ constant pressure can be maintained when a gas is heated by increasing the volume	constant pressure can be . . . Time completed __________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
VOLUME	amount of space occupied by a body.
MASS	amount of matter making up a body.
PHYSICAL PROPERTIES OF A SOLID, A LIQUID AND A GAS	A solid has a volume and a shape of its own. A liquid has a volume of its own, but takes the shape of its container. A gas takes both the volume and the shape of its container.
FLUID	a substance that takes the shape of its container. Both liquids and gasses are considered fluids.
AVERAGE KINETIC ENERGY	the kinetic energy of a typical molecule of a gas. Some molecules of the gas will have less than the average kinetic energy, some more.
PRESSURE	the push exerted by a gas or a liquid on the walls of its container.
GAS LAWS	At constant temperature, a decrease in the volume of a gas causes an increase in pressure, and an increase in volume causes a decrease in pressure. At constant volume, a decrease in the temperature of a gas causes a decrease in pressure, and an increase in temperature causes an increase in pressure. The pressure of a gas can be kept constant when the gas is cooled if, at the same time, the volume is decreased; and the pressure can be kept constant when the gas is heated if, at the same time, the volume is increased.

MASTERY TEST

Time started ____________

1. If the temperature of a gas is increased while the gas is kept at a constant volume, the pressure will:

   a. ☐ decrease
   b. ☐ increase
   c. ☐ either increase or decrease or remain the same
   d. ☐ remain the same

2. If the volume of a gas is increased while the gas is kept at a constant temperature, the pressure will:

   a. ☐ decrease
   b. ☐ increase
   c. ☐ either increase or decrease or remain the same
   d. ☐ remain the same

3. If the temperature of a gas is decreased while the gas is kept at a constant volume, the pressure will:

   a. ☐ decrease
   b. ☐ increase
   c. ☐ either increase or decrease or remain the same
   d. ☐ remain the same

4. If the volume of a gas is decreased while the gas is kept at a constant temperature, the pressure will:

   a. ☐ decrease
   b. ☐ increase
   c. ☐ either increase or decrease or remain the same
   d. ☐ remain the same

5. If the volume of a gas is increased while the temperature is increased, the pressure will:

   a. ☐ decrease
   b. ☐ increase
   c. ☐ either increase or decrease or remain the same
   d. ☐ remain the same

6. Assume that we wanted to keep the gas in a container at a constant pressure. If we heated the gas, the volume of the gas would have to:

a. ☐ decrease
b. ☐ increase
c. ☐ either increase or decrease, depending on the amount of heat
d. ☐ remain the same

Time completed__________________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-876

ED 070909

PM 431 - 69

ADVANCED
GENERAL EDUCATION PROGRAM

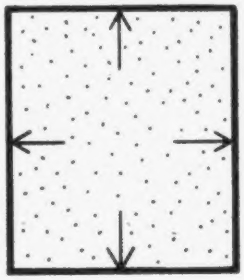
A HIGH SCHOOL SELF-STUDY PROGRAM

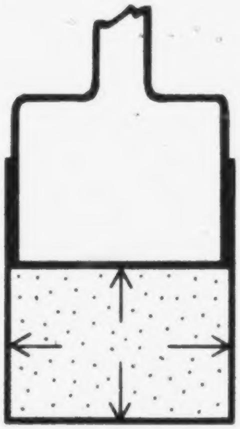
PRINCIPLES OF HEAT ENGINES
LEVEL: II
UNIT: 9
LESSON: 9

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER, 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

1.





The picture on the left above shows a container with immovable walls, and the one on the right shows a container with a movable piston in it. Each container is filled with a gas that exerts pressure on the walls.

Notice that the walls of the first container do not move, but that the piston in the second container does move.

Thus, the pressure of a gas can cause part of its container to move:

☐ when the container has immovable walls

☐ when the container has a movable part such as a piston

☐ in neither case above

. . . has a movable part . . .

2. When a gas in confined in a container with immovable walls, the pressure of the gas: ☐ can cause part of the container to move ☐ does not cause part of the container to move When a gas is confined in a container with a movable part, such as a piston, the pressure of the gas: ☐ can cause part of the container to move ☐ does not cause part of the container to move	does not cause part . . . can cause part of . . .
3. In a previous lesson, you learned that work is defined as the action of a force through a distance. The pressure of a gas exerts a force, and when the gas is confined in a container with a movable part, the force acts on the part and moves it a distance. Thus, when the pressure of a gas causes a part of its container to move, the gas: ☐ performs work ☐ does not perform work If the gas did not cause part of its container to move, the gas: ☐ would perform work ☐ would not perform work	performs work would not perform work
4. Work is performed when the pressure of a gas: ☐ causes part of its container to move ☐ does not cause part of its container to move	causes part of . . .

5. REVIEW FRAME The pressure exerted by a gas on the walls of its container: ☐ depends on the kinetic energy of the gas molecules ☐ does not depend on the kinetic energy of the gas molecules	depends on the kinetic . . .
6. In a previous lesson you learned that the performance of work requires the expenditure of energy. You also learned that many different kinds of energy can be used for work, including electrical energy, light energy and heat energy. You can guess that, when a gas performs work, the kind of energy that is expended is: ☐ electrical energy ☐ heat energy ☐ kinetic energy	kinetic energy
7. The kinetic energy of a gas cannot be expended in the form of work when the gas is confined in a container that: ☐ has a movable part ☐ does not have a movable part	does not have a movable . . .

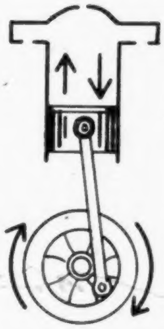
8. When a gas is confined in a container with a movable part, the kinetic energy of the gas: ☐ is expended in the form of work ☐ is not expended in the form of work When a gas is confined in a container that has no movable part, the kinetic energy of the gas: ☐ is expended in the form of work ☐ is not expended in the form of work	is expended in the . . . is not expended . . .
9. Suppose there is an increase in the kinetic energy of a gas (as when a gas is heated). If the container has a movable part, the additional kinetic energy of the gas: ☐ can be expended as work ☐ cannot be expended as work	can be expended as work
10. When there is an increase in the kinetic energy of a gas confined in a container that has no movable part: ☐ all of the additional kinetic energy is expended as work ☐ some of the additional kinetic energy is expended as work ☐ none of the additional kinetic energy is expended as work	none of the additional . . .

11. REVIEW FRAME When a gas is heated, the kinetic energy of the gas: ☐ increases ☐ decreases ☐ neither increases nor decreases That is, a gas: ☐ can acquire additional kinetic energy by the addition of heat energy ☐ cannot acquire additional kinetic energy by the addition of heat energy	increases can acquire additional . . .
12. Since a gas can acquire additional kinetic energy by the addition of heat energy, it is heat energy that is ultimately used to make gas perform work. However, the additional kinetic energy can only be used for work when the container of gas has a movable part (piston). Therefore, all the heat energy is transformed into additional kinetic energy and no work is performed when a gas is heated in a container that: ☐ has a movable part ☐ does not have a movable part	does not have a movable part

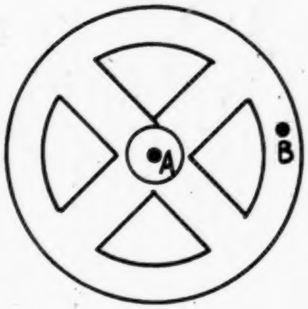
13. When a gas is heated in a container that has no movable part, the heat energy is transformed: ☐ completely into additional kinetic energy ☐ completely into energy expended as work ☐ partly into additional kinetic energy and partly into energy expended as work	completely into additional . . .
14. A device which transforms heat energy into work is called a heat engine. From what you have learned, the essential parts of a heat engine are: ☐ a container ☐ a gas ☐ a movable part ☐ none of the above	a container a gas a movable part
15. The principle of the conservation of energy tells us that no energy is lost or gained when one form of energy is transformed into another. Thus, the combination of additional kinetic energy and energy expended as work that results from the heating of a gas is: ☐ greater than the amount of heat energy added ☐ smaller than the amount of heat energy added ☐ equal to the amount of heat energy added	equal to the amount . . .
16. Can more energy be taken from a heat engine in the form of work than is added in the form of heat? ☐ yes ☐ no	no

17. The rule that no more energy can be taken from a heat engine than is added is called the first law of thermodynamics (thermo = heat, dynamics = motion). You can see that the first law of thermodynamics is based on: ☐ the fact that an increase in kinetic energy in a container with a movable part can result in work ☐ the principle of the conservation of energy	the principle of the . . .
18. According to the first law of thermodynamics: ☐ no more energy can be taken from a heat engine in the form of work than is added in the form of heat ☐ not all the heat energy that is added to a heat engine can be used for work	no more energy can be taken . . .
19. The first law of thermodynamics tells us that we can't get more energy from our heat engine in the form of work than we add in the form of heat. We can't even get all of the heat put into the engine converted to work because some of the heat put into the machine is given off in the exhaust of the engine. Therefore, when there is an increase in the kinetic energy of the gas confined in our heat engine: ☐ all of the additional kinetic energy is expended as work ☐ some of the additional kinetic energy is expended as work ☐ none of the additional kinetic energy is expended as work	some of the additional . . .

20. Heat energy is transformed partly into work and partly into additional kinetic energy when a gas is heated in a container that: ☐ has a movable part ☐ does not have a movable part	has a movable part
21. Can more energy be taken from a heat engine in the form of work than is added in the form of heat? ☐ yes ☐ no Can all of the heat energy added to a heat engine be transformed into work? ☐ yes ☐ no	no no
22. The rule that not all the energy that is added to a heat engine can be used for work is called the second law of thermodynamics. The second law of thermodynamics is based on: ☐ the fact that not all the heat energy added to a heat engine can be used for work ☐ the principle of the conservation of energy	the fact that not all . . .

23. MATCH each of the following laws of thermodynamics with its proper definition: A. No more energy can be taken from a heat engine in the form of work than is added in the form of heat B. Not all the heat energy that is added to a heat engine can be used for work 1. _____ first law of thermodynamics 2. _____ second law of thermodynamics	A B
24.  Most heat engines have more than one moving part. For example, the essential moving parts of an automobile are pistons and wheels. Gas pressure moves the pistons and the pistons move the wheels. A piston and a wheel are shown above. The pictures show that the piston has a ☐ back-and-forth motion ☐ rotational motion and that the wheel has a ☐ back-and-forth motion ☐ rotational motion	back-and-forth motion rotational motion

25.



How is the back-and-forth movement of a piston converted into the rotational movement of the wheel ?

A wheel is shown above. Two positions on the wheel are marked.

You can see that Position A is:

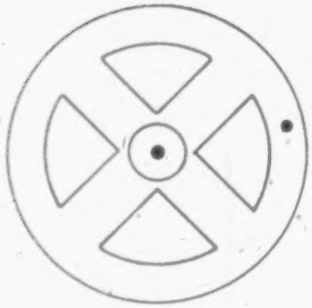
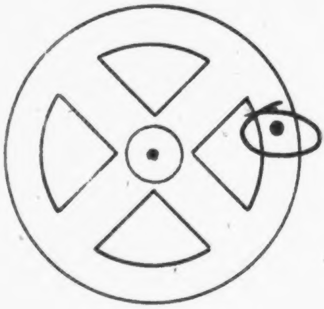
- ☐ at the center of the wheel
- ☐ off the center of the wheel

and that Position B is:

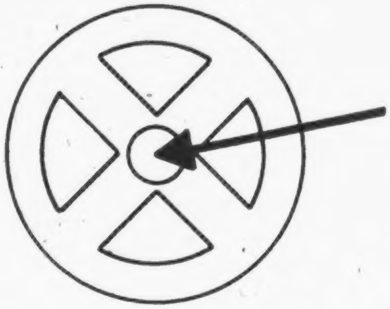
- ☐ at the center of the wheel
- ☐ off the center of the wheel

at the center of the wheel

off the center of the wheel

26. The position at the center of a wheel is called the center position, and a position off the center is called an eccentric position. CIRCLE the eccentric position(s) on the wheel shown below: 	
27. An eccentric position on a wheel is a position: ☐ at the center of the wheel ☐ off the center of the wheel	off the center of the wheel

28.

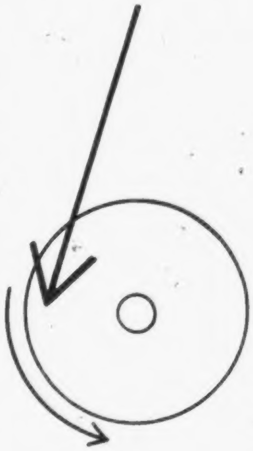
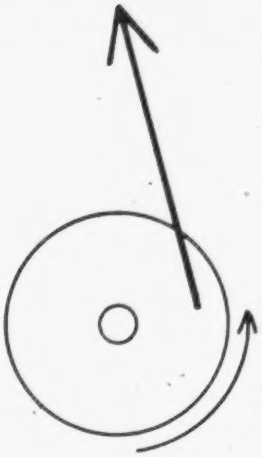


The picture above shows a force being applied to the center position of a wheel.

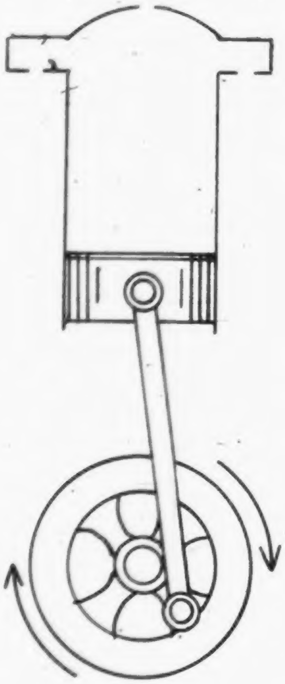
You can see that the wheel:

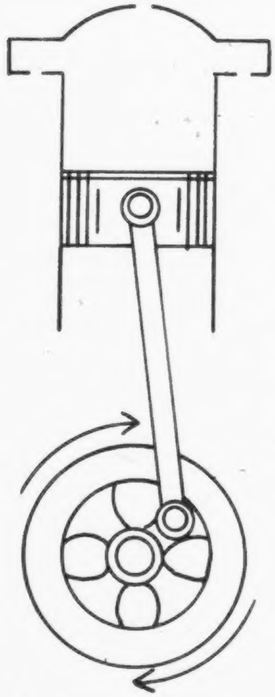
- ☐ does not move
- ☐ moves in a straight line
- ☐ rotates

moves in a straight line

29.  1.  2.	
In the pictures above, the force is applied to an eccentric position on a wheel. When the force is first applied, as in Picture 1, the wheel: ☐ does not move ☐ moves in a straight line ☐ begins to rotate	begins to rotate
Then, when the wheel reaches a new position, as shown in Picture 2, and a reverse force is applied, the wheel: ☐ continues to rotate ☐ moves in a straight line ☐ stops	continues to rotate
30. A wheel can be made to rotate through the application of a force first in one direction, then in the reverse direction, to: ☐ an eccentric position ☐ its center position	an eccentric position

PANEL 1





31. When a piston is attached to an eccentric position the force must go: ☐ steadily in one direction ☐ first in one direction, then in the reverse direction	first in one direction . . .
32. REFER TO PANEL 1 Suppose the piston of a heat engine is connected by means of a rod to an eccentric position on a wheel, as shown in Panel 1. You can see that, when the piston moves in one direction, the rod: ☐ applies a force to the wheel ☐ does not apply a force to the wheel	applies a force to the wheel
and that, when the piston moves back, in the opposite direction, the rod: ☐ applies a reverse force to the wheel ☐ does not apply a reverse force to the wheel	applies a reverse force . . .
Thus, the connection of a piston to an eccentric position on a wheel, by means of a rod: ☐ causes a wheel to go back-and-forth ☐ causes a wheel to rotate ☐ does not cause a wheel to rotate	causes a wheel to rotate

33.

The back-and-forth motion of a piston can be converted to the rotational motion of a wheel by connecting the piston rod to:

☐ an eccentric position on the wheel
☐ a position at the center of the wheel

an eccentric position . . .

Time completed ______________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
HOW WORK IS PERFORMED BY A GAS	When a gas is confined to a container with a movable part, the pressure exerted by the gas causes the part to move. The pressure is a kind of force, and, consequently, the movement of the part is work. The pressure of the gas is due to its kinetic energy. When the gas performs work, part of its kinetic energy is expended. The kinetic energy of the gas can be increased through heating.
HEAT ENGINE	a device which transforms heat energy into work. Its essential parts are a container, a gas and a movable part.
FIRST LAW OF THERMODYNAMICS	No more energy can be taken from a heat engine in the form of work than is added in the form of heat.
SECOND LAW OF THERMODYNAMICS	Not all the heat energy added to a heat engine can be used for work.
ECCENTRIC POSITION	a position off the center of a wheel.
HOW THE BACK-AND-FORTH MOTION OF A PISTON IS CONVERTED INTO THE ROTATIONAL MOTION OF A WHEEL	The piston is connected by means of a rod to an eccentric position on the wheel. The back-and-forth motion of the piston causes the wheel to rotate first half-way, then all-the-way.

MASTERY TEST

Time started ________________

1. When a gas is heated in a container that has no movable part, the heat energy is transformed:

   a. ☐ completely into additional kinetic energy

   b. ☐ completely into energy expended as work

   c. ☐ partly into additional kinetic energy and partly into energy expended as work

2. A container with a movable part is used in a heat engine so that:

   a. ☐ the heat energy can be transformed completely into additional kinetic energy

   b. ☐ the kinetic energy of the heated gas can apply pressure to the movable part

   c. ☐ work can be performed

3. According to the first and second laws of thermodynamics:

   a. ☐ an increase in kinetic energy in a container with a movable part can result in work

   b. ☐ no more energy can be taken from a heat engine than is added

   c. ☐ not all the energy added to a heat engine can be used as work

   d. ☐ the principle of the conservation of energy holds true for a heat engine

4. To convert the motion of a piston to a rotational motion of a wheel:

   a. ☐ the piston must be able to supply its own energy

   b. ☐ the piston must be connected to a position off the center of the wheel

   c. ☐ the piston must move first in one direction, then in the reverse direction

   d. ☐ the piston must rotate the same way as the wheel

5. A heat engine:

   a. ☐ converts heat energy into the energy of motion

   b. ☐ generates energy in the form of work that is equal to the amount of energy added as heat

   c. ☐ must have a container, a gas and a movable part

   d. ☐ uses the work generated by the pressure of a heated gas

Time completed _______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-877

ED 070909

PM 431 - 70

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

SOUND AND SOUND WAVES

LEVEL: II
UNIT: 9
LESSON: 10

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

PANEL 1

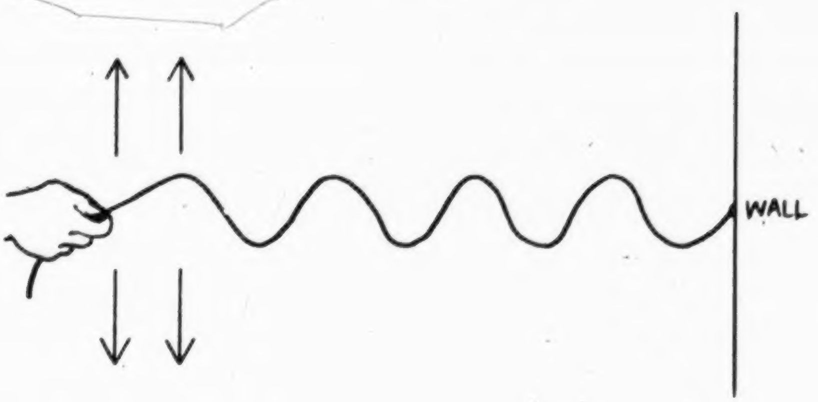


Figure 1.

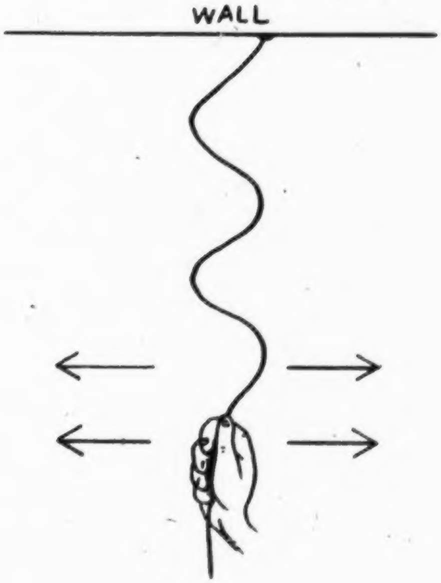


Figure 2.

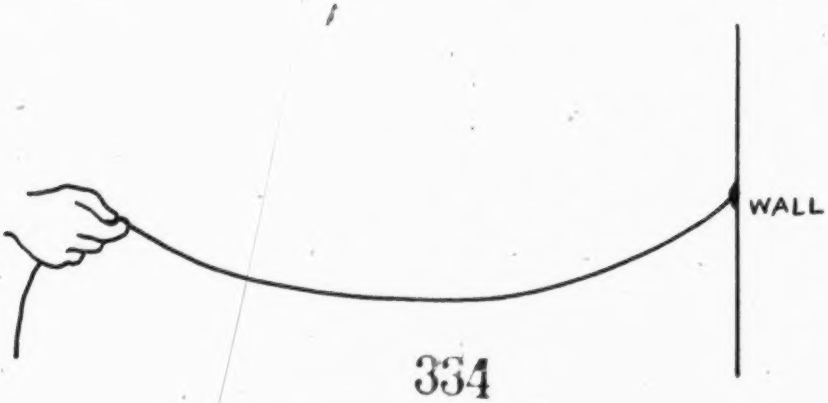


Figure 3.

1. PREVIEW FRAME In this lesson you will learn more about sound: how it travels and the different forms it takes and how you hear so many different sounds. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
2. REFER TO PANEL 1 Shown in the panel are three figures. In each figure, one end of a rope is attached to a wall and the other end is held in someone's hand. By looking at the figures, LABEL each of the statements below either I, II, or III.	
_____ The hand is moving from side to side.	II
_____ The hand is moving up and down.	I
_____ The hand is not moving.	III
_____ The rope is moving from side to side.	II
_____ The rope is moving up and down.	I
_____ The rope is not moving.	III
3. REFER TO PANEL 1 In the two figures that show a hand movement, the hand is moving:	
☐ in the form of a wave ☐ in a straight line	in a straight line
The ropes are moving: ☐ in a straight line ☐ in a wavelike motion	in a wavelike motion

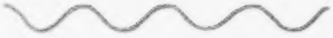
4.

REFER TO PANEL 1

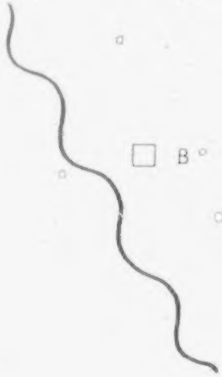
When something moves in a wavelike form, we say it oscillates, or vibrates.

Which of the figures in Panel 1 show the rope oscillating?

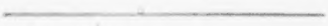
CHECK each figure below which shows oscillation.



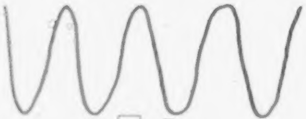
☐ A



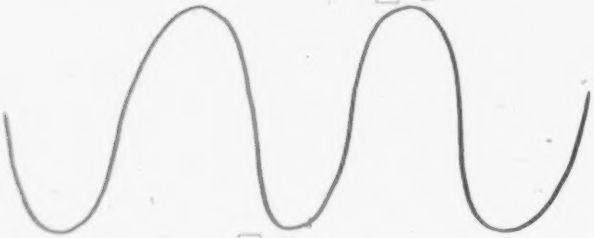
☐ B



☐ C



☐ D



☐ E

A

B

D

E

PANEL 2

Figure 1.

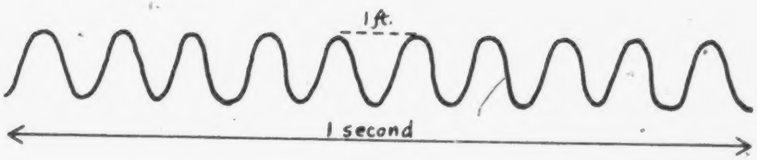

1 ft.
1 second

Figure 2.

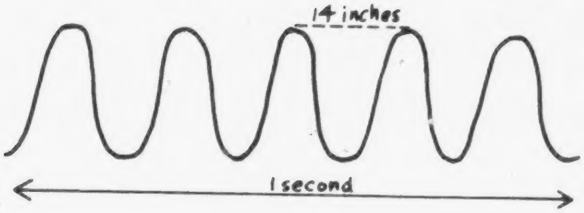
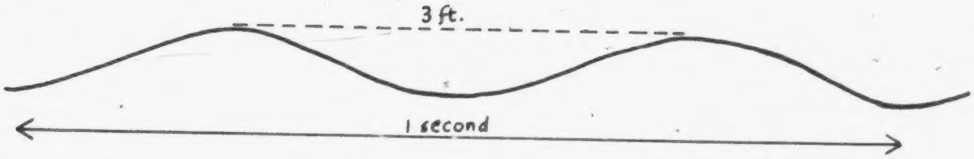

14 inches
1 second

Figure 3.


3 ft.
1 second

5. REFER TO PANEL 1 What provides the energy that causes the ropes in Figures 1 and 2 to oscillate or vibrate ? ________________	someone's hand (or equivalent response)
6. REFER TO PANEL 1 The source that provides the energy for the rope to oscillate is called the vibrating source. Which of the figures shown in Panel 1 show a vibrating source ? ____________ What is the source ? ____________	I, II a hand (or equivalent response)
7. REFER TO PANEL 2 Shown on the panel are three different wave forms. Notice that on each form the distance between the peaks of two adjacent waves has been marked off. What is the distance between wave peaks in Figure 1 ? ______ In Figure 2 ? ______ In Figure 3 ? ______ Notice that the time during which these vibrations have occurred is: ☐ one minute ☐ one second How many oscillations occur in Figure 3 during this time ? ______	 1 foot 14 inches 3 feet one second 2

8. REFER TO PANEL 2 In Figure 3, two vibrations occur during one second. Each vibration covers a distance of three feet. How far does the wave peak travel during 1 second? __________	6 feet
9. REFER TO PANEL 2	
How many vibrations occur during 1 second in Figure 1? _____	10
What is the distance that the wave travels during 1 second? _____	10 feet
In Figure 2, what is the distance in feet the wave travels during 1 second? __________	5 5/6 feet
10. REFER TO PANEL 2 The number of vibrations per second is called the wave frequency. The distance between similar points on two adjacent waves is called the wave length. The number of feet per second that a wave travels is called the wave speed or velocity.	
What is the wave frequency of Figure 1? _____	10/sec.
What is the wave length of Figure 1? _____	1'
What is the velocity of Figure 1? _____	10'/sec.
What is the wave frequency of Figure 2? _____ of Figure 3? _____	5/sec. 2/sec.
What is the wave length of Figure 2? _____ of Figure 3? _____	1'2" 3'
What is the velocity of Figure 2? _____ of Figure 3? _____	5'10"/sec. 6'/sec.

PANEL 3

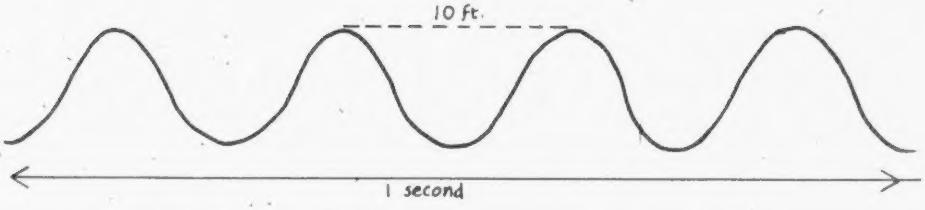

10 ft.
1 second

Figure 1.

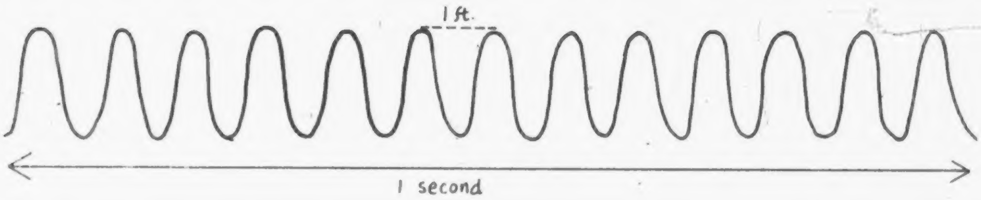

1 ft.
1 second

Figure 2.

11.

You have found the velocity or wave speed for all three of the figures shown on the panel.

How did you find the velocity in each case?

☐ by adding the wave length to the wave length
☐ by dividing the frequency by the wave length
☐ by dividing the wave length by the frequency
☐ by multiplying the frequency by the wave length

by multiplying the . . .

12.

REFER NOW TO PANEL 3

Panel 3 shows two wave forms that are similar to the previous examples you have seen.

For Figure 1, give:

the wave frequency	_____	4/sec.
the wave length	_____	10'
the velocity	_____	40'/sec.

For figure 2, give:

the wave frequency	_____	13/sec.
the wave length	_____	1'
the wave speed	_____	13'/sec.

13.

MATCH the terms below with the descriptions of wave motion.

A. distance between wave peaks

B. number of vibrations per second

C. speed at which wave travels

1. _____ frequency
2. _____ velocity
3. _____ wave length

1. B
2. C
3. A

14.

Now that you have seen what the three basic characteristics of sound waves are, you will learn how they travel and the changes that occur as they travel.

NO RESPONSE REQUIRED

GO ON TO THE NEXT FRAME

PANEL 4

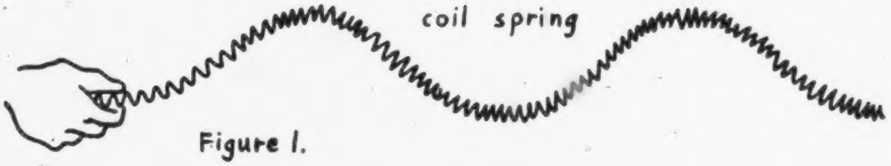

coil spring

Figure 1.

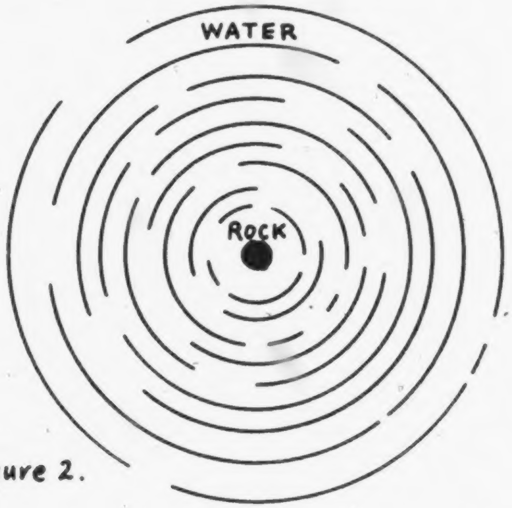


Figure 2.

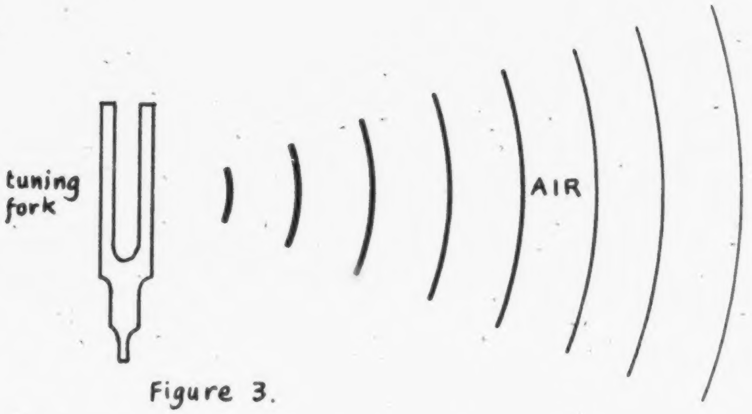

tuning fork
AIR

Figure 3.

15.	
REFER NOW TO PANEL 4	
Shown on the panel are examples of two different waves. In Figure 1, what is the source of vibrations ? ___________	a hand
In Figure 2, what is the source of vibrations ? ___________	a rock
In Figure 3, what is the source of vibrations ? ___________	a tuning fork
In Figure 1, the waves produced by the vibrating source travel through: ☐ air ☐ a coil spring	a coil spring
In Figure 2, the waves travel through: ☐ air ☐ a coil spring ☐ water	water
In Figure 3, the waves travel through: ☐ air ☐ a coil spring ☐ water	air
16.	
REFER TO PANEL 4	
A substance through which waves travel is known as a medium.	
Through what medium are the waves traveling:	
In Figure 1 ? ___________	a coil spring
In Figure 2 ? ___________	water
In Figure 3 ? ___________	air

17. REFER TO PANEL 4 By referring to the panel, you can surmise that waves can travel through mediums that are: ☐ gaseous ☐ liquid ☐ solid	gaseous liquid solid
18. What is a medium? ☐ any wave movement ☐ a substance through which a wave can travel ☐ a vibrating source which produces a wave Without referring to the panel, give three examples of mediums.	a substance through which . . . air water coil spring (any order)
19. A man strikes a bell with his hand. The bell vibrates and causes sound waves to travel through the air. In the example above: What is the medium? _______________ What is the vibrating source? _______________ What is the source of energy for the vibrating source? _______________ When energy is applied to the bell, what travels? ☐ sound waves ☐ air	air a bell a hand sound waves

PANEL 5

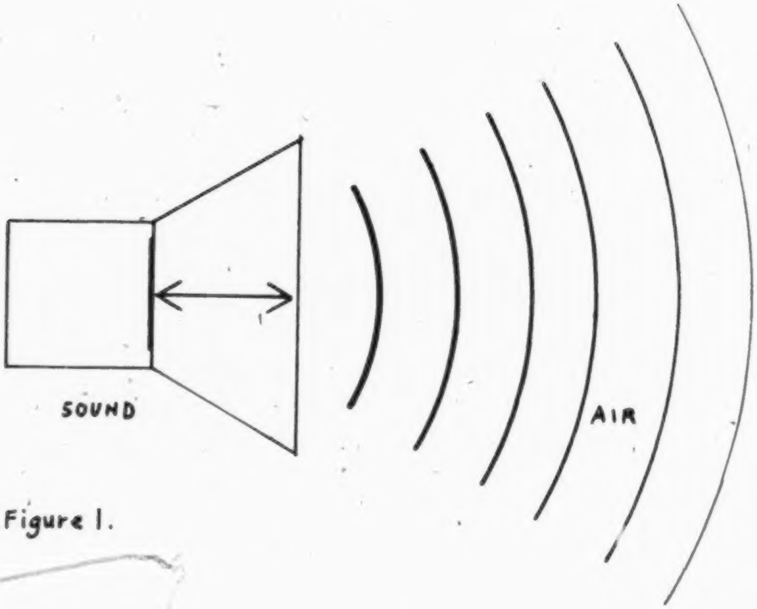


Figure 1.

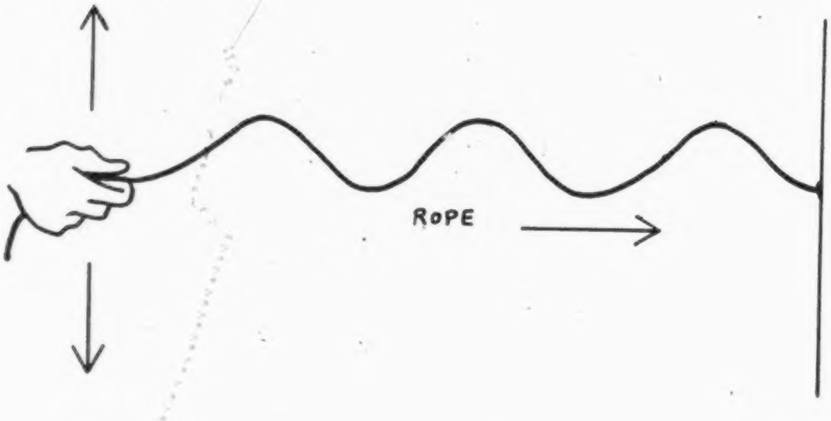


Figure 2.

13

20.

REFER NOW TO PANEL 5

Shown in the panel are two different types of waves.

In Figure 1, the vibrating source is a loudspeaker. In which direction is the vibrating source acting?

☐ ↔

☐ ↕

In Figure 2, in which direction is the vibrating source acting?

☐ ↔

☐ ↕

↔

↕

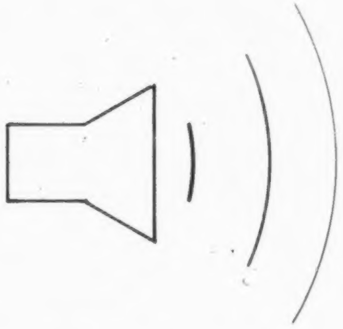
21.

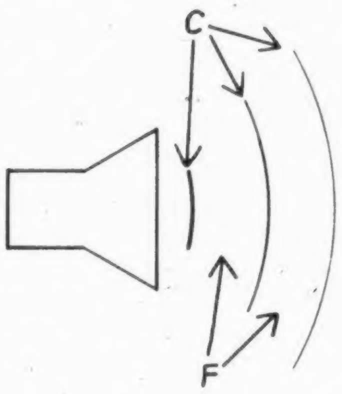
REFER TO PANEL 5

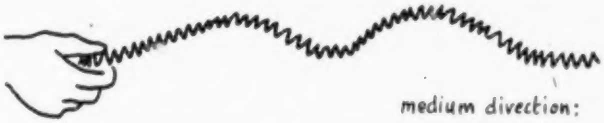
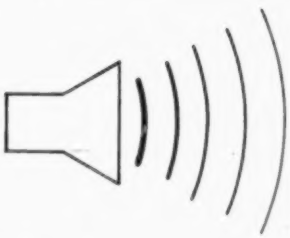
In Figure 1, we see that the medium, air, is changed by the wave moving through it.

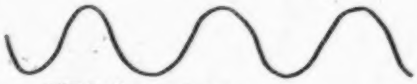
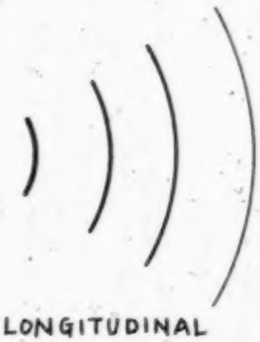
Molecules of air are pushed together very closely at the vibrating source, and as they move away cause waves of air pressure starting at the loudspeaker.

In the diagram below, LABEL C the areas where the molecules is/are close together. LABEL F the areas where the molecules is/are few.



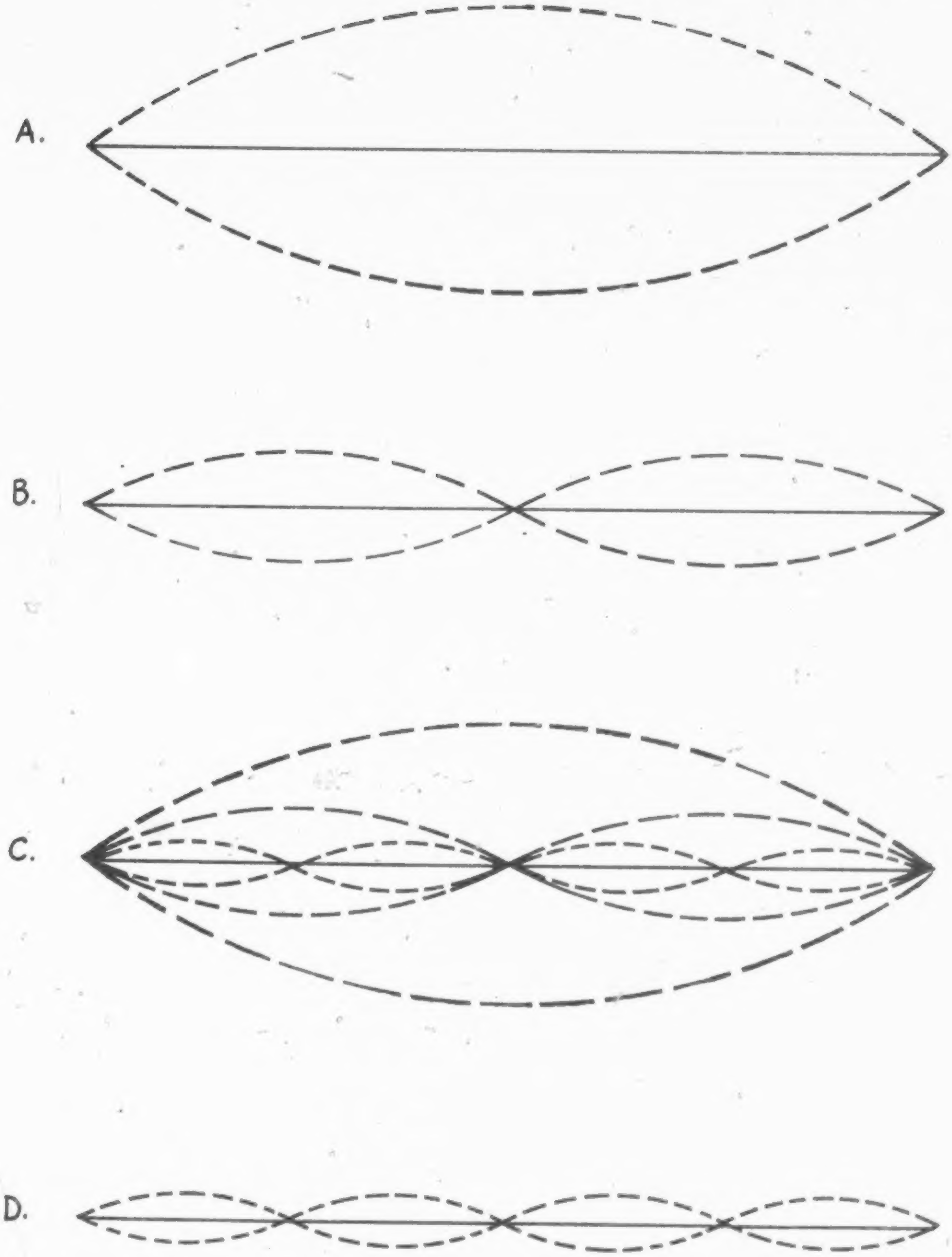


22.	
REFER TO PANEL 5	
In Figure 1, in which direction does the vibrating source move? ☐ forward and backward ☐ up and down	forward and backward
In Figure 1, in which direction does the medium move? ☐ forward and backward ☐ up and down	forward and backward
In which direction does the wave travel? ____________	forward
In Figure 2, in which direction does the vibrating source move? ☐ forward and backward ☐ up and down	up and down
In Figure 2, in which direction does the medium move? ☐ forward and backward ☐ up and down	up and down
In which direction does the wave travel? ____________	forward
23.	
DO NOT REFER TO PANEL	
In the diagrams below, DRAW arrows to show: 1. the direction in which the medium moves 2. the direction in which the wave travels	
 medium direction: wave direction:	m d: ↕ w d: ⟶
 medium direction: wave direction:	md: ↔ wd: ⟶

24. REFER TO PANEL 5 In which figure does the medium move at right angles to the direction of the wave movement? _____ In which figure do both the medium and the wave move in the same line of direction? _____	2 1
25. When the medium moves in the same line of direction as the direction of the wave, the wave is called longitudinal. When the medium moves at right angles to the direction of the wave, the wave is called transverse. DRAW and LABEL either "longitudinal" or "transverse" an example of each type of wave.	 TRANSVERSE  LONGITUDINAL
26. REFER TO PANEL 5 Which wave shown in the panel is longitudinal? _____ Which is transverse? _____	1 2

27. REFER TO PANEL 5 The wave in Figure 1 is longitudinal because: ☐ the wave travels in a direction at right angles to the movement of the medium ☐ the wave travels in the same line of direction as the medium	. . . direction as the medium
28. REFER TO PANEL 5 The wave in Figure 2 is transverse because: ☐ the wave travels in a direction at right angles to the movement of the medium ☐ the wave travels in the same line of direction as the medium	. . . in a direction at right . . .
29. PREVIEW FRAME The following frames are concerned with the way in which sounds are produced and the characteristics of the vibrations that determine what you hear. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

PANEL 6



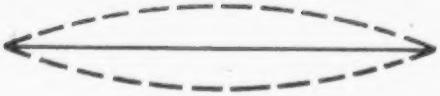
30.	
NOW REFER TO PANEL 6	
Shown in the panel are four different pictures of a string vibrating.	
By referring to the Panel, MATCH the following:	
A. Figure A — 1. _____ each half of the string is vibrating separately	1. B, C
B. Figure B	
C. Figure C — 2. _____ each fourth of the string is vibrating separately	2. C, D
D. Figure D — 3. _____ the string is vibrating as a whole	3. A, C
31.	
REFER TO PANEL 6	
Suppose you pluck a string on a guitar. The string will vibrate as a whole unit, but at the same time, half of it may be vibrating separately with a different frequency, and fourths of it may be vibrating with still a different frequency.	
Which figure on the panel shows all of these happening on the same string at the same time? _____	C

32. REFER TO PANEL 6 When a string vibrates as a whole with, say, a frequency of 400 vibrations per second, it may vibrate in halves with a frequency of 800 vibrations per second, and in fourths with a frequency of 1600 vibrations per second. If, in Figure A, the string is vibrating with a frequency of 300 vibrations per second, what will the frequency of Figure B be? ________________ What will be the frequency of Figure D? ______________	600 vibrations per second 1200 vibrations per second (or equivalent response)
33. REFER TO PANEL 6 Which vibrates with the lowest frequency? ☐ the string shown in Figure A ☐ the string shown in Figure B ☐ the string shown in Figure D Which vibrates with the highest frequency? ☐ the string shown in Figure A ☐ the string shown in Figure B ☐ the string shown in Figure D	. . . Figure A . . . Figure D
34. REFER TO PANEL 6 The lowest frequency with which a source vibrates is called its fundamental frequency. When a source vibrates in halves or thirds or fourths, the resulting frequencies are called overtones. Which figure(s) on the panel show(s) a string vibrating with its fundamental frequency? _____ Which figure(s) show(s) a string vibrating with overtones? _____	A, C B, C, D

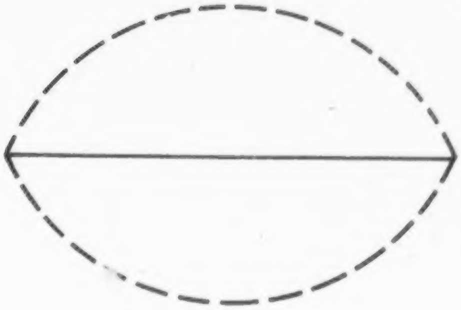
35. What is the fundamental frequency of a sound source? ☐ the frequency produced by the vibration of fractions of the source ☐ the frequency produced by the vibration of the source as a whole	. . . source as a whole
36. MATCH the following: A. a source vibrates as a whole B. a source vibrates in fourths C. a source vibrates in halves D. a source vibrates in thirds 1. _____ fundamental frequency 2. _____ overtones	1. A 2. B, C, D

PANEL 7

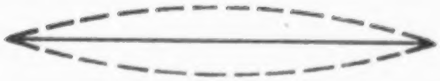
A.



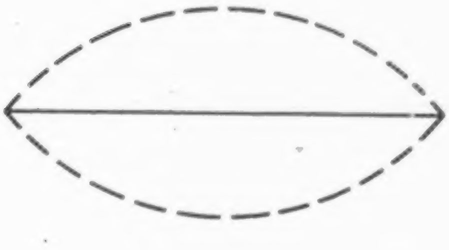
B.

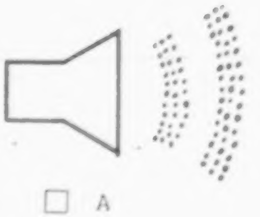
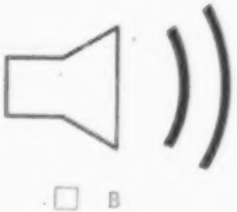


C.



D.



37. REFER TO PANEL 7 Shown on the panel are four different pictures of the same string. In each picture, the string is vibrating with its fundamental frequency, that is: ☐ it is vibrating as a whole ☐ only parts of it are vibrating	it is vibrating as a whole
In which case was the string plucked most softly? _____	C
In which case was the string plucked the hardest? _____	B
38. When a string is plucked harder or softer, the fundamental frequency and the overtones remain the same, but the loudness or softness of the tone changes. The sound waves still move through the air at the same frequency, but the air molecules are pushed closer together as the loudness increases. In which diagram below would the sound be louder?  ☐ A  ☐ B	B

39.

REFER TO PANEL 7

The fundamental frequency of the string shown in Figure A is 300 vibrations per second.

USE this information to fill in the chart below:

	Fundamental Frequency	Softest	Soft	Loud	Loudest
Figure A					
Figure B					
Figure C					
Figure D					

FF	S	S	L	L
300		X		
300				X
300	X			
300			X	

40.

REFER TO PANEL 7

The degree to which a sound wave compresses molecules of air as it moves through it is called its amplitude.

Which of the strings shown in the panel would have the greatest amplitude? (HINT: The greater the back and forth movement of the source, the more the air is compressed) _____

Which would have the smallest amplitude? _____

B

C

41. When sound waves are produced by a vibrating source, and they reach a person's ear, the eardrum vibrates and the person hears the sound. As a sound wave strikes the eardrum, it causes it to vibrate with corresponding: ☐ amplitude ☐ frequency ☐ length ☐ speed	frequency
42. If sound waves are to be perceived by the human ear, they must have a frequency ranging between 20 and 20,000 vibrations per second. CHECK the frequencies below that can be heard by the human ear: ☐ 10 vibrations per second ☐ 150 vibrations per second ☐ 1500 vibrations per second ☐ 2000 vibrations per second ☐ 25,000 vibrations per second	150 vibrations per second 1500 vibrations per second 2000 vibrations per second
43. CIRCLE the word in the statement below which describes the medium. UNDERLINE the phrase in the statement below which describes the frequency. Waves travelling through air vibrating at a rate of 20 - 20,000 vibrations per second can be received by most human ears.	air 20 - 20,000 vibrations per second

44.	
If the frequency of a sound wave is low (20 vibrations per second) the sound when it is received by the ear will also be low.	
A sound with a frequency of 15,000 vibrations would:	
☐ sound high ☐ sound low	sound high
45.	
The highness or lowness of a sound heard by the ear is called pitch.	
LABEL each of the following LP for low pitch or HP for high pitch:	
_____ a bass drum	LP
_____ a bull bellowing	LP
_____ a cat meowing	HP
_____ the sound of a flute	HP
46.	
When the frequency of a sound wave is low the:	
☐ pitch is high ☐ pitch is low ☐ pitch cannot be determined	pitch is low
The pitch of any sound depends upon:	
☐ frequency ☐ loudness ☐ wave speed	frequency

47. Frequencies higher than the fundamental frequency are called: ☐ loudness ☐ overtones ☐ pitch	overtones
48. In the same way the human ear perceives a certain range of frequencies, it also perceives a certain range of amplitude. If the amplitude is too great, it can cause pain or damage to the eardrum. If the amplitude is too small, the sound will not be perceived. MATCH the following: A. amplitude too great B. amplitude too small 1. _____ pain or damage may result 2. _____ the sound will not be perceived	1. A 2. B
49. You may be wondering why the same melody sounds different when played, for example, on a saxophone than it does when played on a flute. The difference in sound is caused by the overtones produced by the vibrations of each instrument. The flute has a relatively pure sound, and very few overtones. The saxophone produces a rich sound and has many overtones. You can guess that more overtones are produced by: ☐ a bass fiddle ☐ a bugle	a bass fiddle

50.	
Which do we generally perceive as having a "richer" sound? ☐ an organ ☐ a flute	an organ
Which would produce the greater number of overtones? ☐ an organ ☐ a flute	an organ
51.	
When an organ produces sounds of the same fundamental frequencies as a flute, the sounds of the organ are "richer" than those produced by the flute. We say that the quality of the sounds produced by an organ is different from the quality of the sounds produced by a flute.	
The quality of sound produced by an instrument: ☐ depends on the fundamental frequencies produced by the instrument ☐ depends on the overtones produced by the instrument	depends on the overtones . . .
52.	
MATCH the following: A. loudness B. pitch C. quality	
1. _____ the highness or lowness of a sound	1. B
2. _____ the richness of a sound	2. C

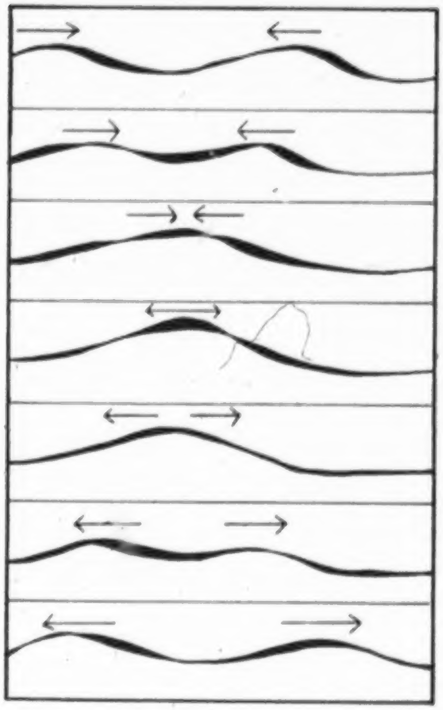


Figure 1

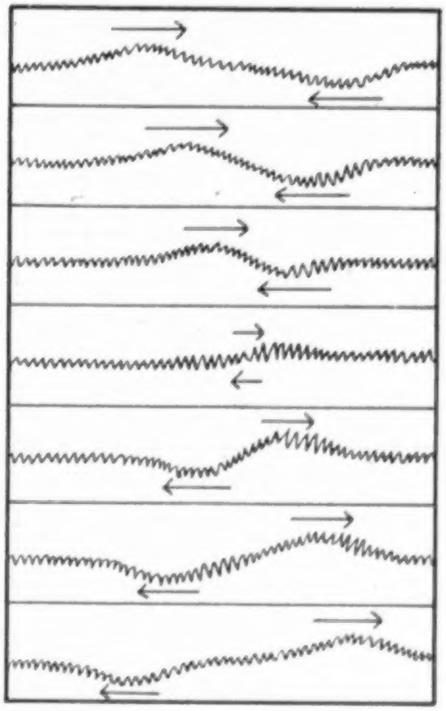
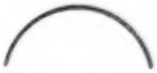
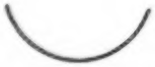
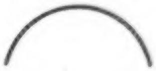
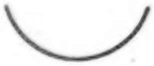
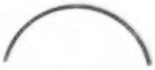
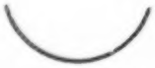
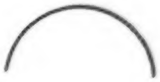
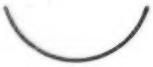
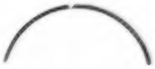
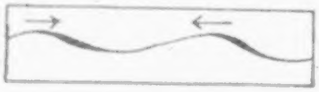
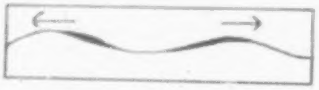
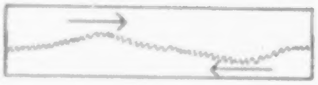
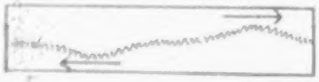
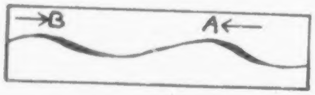
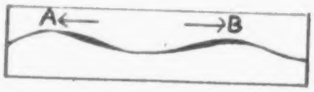
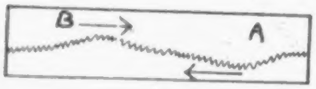
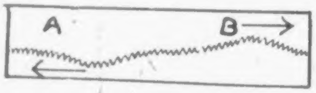


Figure 2

53. MATCH the following: A. loudness B. pitch C. quality 1. _____ depends on amplitude of vibration 2. _____ depends on frequency of vibration 3. _____ depends on the number of overtones	1. A 2. B 3. C
54. PREVIEW FRAME The following frames will discuss what happens when sound waves "run into" each other. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
55. REFER TO PANEL 8 Shown on the panel are two different illustrations of waves "running into" each other. In Figure 1 there are two waves marked by arrows. Both waves look like (CHECK one):   In Figure 2 there are also two waves marked by arrows. The wave on the right looks like (CHECK one):   The wave on the left looks like (CHECK one):  	  

56. REFER TO PANEL 8 The two waves shown in Figure 1: ☐ are different from each other ☐ are similar to each other The two waves shown in Figure 2: ☐ are different from each other ☐ are similar to each other	are similar to each other are different from each other
57. REFER TO PANEL 8 Notice that in both figures the two waves move toward the middle and then pass each other. Two of the drawings from each figure are shown below. LABEL the wave that begins on the right A in each case, and the one that begins on the left B.    	   

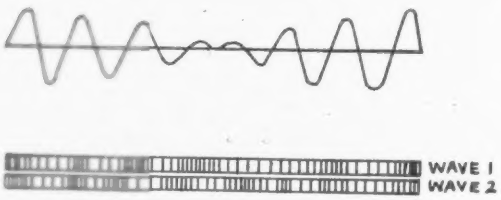
58. REFER TO PANEL 8 In Figure 1, picture 4, as the two waves meet each other you can see: ☐ one wave ☐ two waves ☐ no wave	one wave
In Figure 2, picture 4, as the two waves meet each other you can see: ☐ one wave ☐ two waves ☐ no wave	no wave
59. REFER TO PANEL 8 In Figure 1, picture 4, you can see that when two waves meet that have the same form, they combine: ☐ and cancel each other at that point ☐ into one wave larger than either of them separately	into one wave larger . . .
In Figure 2, picture 4, you can see that the two waves: ☐ combine into one wave larger than either wave separately ☐ meet and cancel each other at that point	meet and cancel each other . . .
In Figure 2 the two waves have: ☐ different forms ☐ the same form	different forms

60. REFER TO PANEL 8 When two waves with the same motion meet, they combine into one wave larger than either of them separately. This is known as constructive interference. When two waves that have opposite motion meet, they tend to cancel each other. This is known as destructive interference. Which of the figures in Panel 8 shows constructive interference? _____ Which shows destructive interference? _____	1 2
61. MATCH the following: A. constructive interference B. destructive interference 1. _____ two waves that have the same motion meet and create a larger wave 2. _____ two waves with an opposite motion meet and tend to cancel each other	1. A 2. B

62.

Just as you saw two transverse waves meeting and either combining or cancelling, longitudinal waves also meet and tend either to combine or to cancel each other.

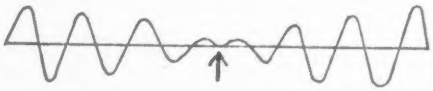
LOOK AT the diagram below:



By looking at the line above the two sound waves, LABEL the point on the waves where interference would occur.

This interference is:

☐ constructive
☐ destructive



destructive

63. If you walk through a room where a stereo record player is going, you can notice the sound changing as you move through the room. At points the sound will be very loud. This is due to: ☐ constructive interference ☐ destructive interference	constructive interference
At other points in the room some sounds will be very low or may even disappear completely. This is due to: ☐ constructive interference ☐ destructive interference	destructive interference
64. When waves meet and tend to cancel each other out by opposing motion the result is known as: ☐ constructive interference ☐ destructive interference ☐ quality ☐ silence	destructive interference
65. Interference is the result of: ☐ two waves travelling through a medium and meeting ☐ two waves travelling through a medium and never meeting	. . . and meeting Time completed ____________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

WORD	DEFINITION
WAVE FREQUENCY	the number of vibrations per second; pitch depends on the frequency of vibrations.
FUNDAMENTAL FREQUENCY	the lowest frequency with which a source vibrates; this frequency is produced by the vibration of the source as a whole.
OVERTONES	vibrations in halves or thirds or fourths above the fundamental frequency; only part of the source vibrates to produce overtones.
	TONE QUALITY: depends upon the number of overtones.
WAVE LENGTH	the distance between wave peaks.
WAVE SPEED OR WAVE VELOCITY	the number of feet per second that a wave travels.
MEDIUM	a substance through which waves travel Examples: a gaseous medium (air); a liquid medium (water); a solid medium (coil spring).
VIBRATION	that which causes sound waves to travel. Example: striking a bell will create vibrations causing sound waves to travel through the air.
LONGITUDINAL SOUND WAVE	a wave which travels in the same line of direction as the medium.
TRANSVERSE SOUND WAVE	a wave that travels in a direction at right angles to the movement of the medium.
AMPLITUDE	As sound waves vibrate, they move back and forth: the greater the back and forth movement of the sound source, the more air is compressed - the amplitude of a sound wave is the degree to which a sound wave compresses molecules of air as it moves through it; amplitude is often described as loudness.
CONSTRUCTIVE INTERFERENCE	occurs when two waves that have the same motion meet and create a larger wave.

WORD	DEFINITION
DESTRUCTIVE INTERFERENCE	occurs when two waves with an opposite motion meet and tend to cancel each other.

MASTERY TEST

Time started ______________

1. What term is used to refer to what happens when two sound waves with an opposite motion meet?

   a. ☐ constructive interference

   b. ☐ destructive interference

2. MATCH the following:

   A. wave frequency

   B. wave length

   C. wave velocity

   1. _____ the distance between similar points on two adjacent waves

   2. _____ the number of feet per second that a wave travels

   3. _____ the number of vibrations per second

3. What is a medium?

   a. ☐ a substance through which a wave can travel

   b. ☐ the vibrating source which produces a wave

4. A longitudinal wave is one in which:

   a. ☐ the medium moves at right angles to the wave direction

   b. ☐ the medium moves in the same line of direction as the wave

5. MATCH the following:

   A. fundamental frequency

   B. overtones

   1. _____ produced when a sound source vibrates as a whole

   2. _____ produced when a sound source vibrates in halves, thirds or fourths

6. MATCH the following:

A. loudness
B. pitch
C. quality

1. _____ amplitude
2. _____ frequency
3. _____ fundamental frequency
4. _____ overtones

Time completed _______________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-878

ED 070909

PM 431 - 71

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

LIGHT WAVES AND PARTICLES
LEVEL: II
UNIT: 9
LESSON: 11

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

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U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

1. PREVIEW FRAME In the preceding lesson unit you learned about wave phenomena in general, and about sound waves in particular. The next two lessons will be devoted to the study of the properties and behavior of light, which is another wave phenomenon. In the following lesson you will learn some basic facts about the nature of light. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME
2. Imagine that you are outdoors on a sunny day. You can see the sun, buildings, and people. The light that lets you see the buildings comes originally from: ☐ the buildings ☐ the sun	the sun
3. The light by which we see buildings on a sunny day originally comes from the sun. The light from the sun bounces off the buildings and enters our eyes. This shows us that light: ☐ can travel from object to object ☐ cannot travel from object to object	can travel from object . . .

4.	
Light can travel from one object to another. Can light travel through the air?	
☐ yes ☐ no	yes
Air is a molecular medium. Water, glass, and steel are also molecular media. Sound can travel through all of these media.	
Light:	
☐ can travel through steel ☐ cannot travel through steel	cannot travel through steel
Light can travel through:	
☐ all media ☐ only some media	only some media
5.	
Light can travel through only some molecular media. Light also travels through a vacuum, where there are almost no molecules at all. Outer space is such a vacuum.	
Can sound travel in a vacuum?	
☐ yes ☐ no	no
Sound:	
☐ does not need a medium in which to travel ☐ needs a medium in which to travel	needs a medium in which . . .
Light:	
☐ does not need a medium in which to travel ☐ needs a medium in which to travel	does not need a medium . . .

6. Sound is transmitted in the form of waves which can travel only through molecular media. Light is transmitted in the form of waves which can travel through some molecular media. Light can also travel through a vacuum. Light waves are: ☐ different from sound waves ☐ the same as sound waves	different from sound waves
7. Sound waves can be transmitted through: ☐ a medium only ☐ a vacuum only ☐ both a medium and a vacuum	a medium only
Light waves can travel through: ☐ a medium only ☐ a vacuum only ☐ both a medium and a vacuum	both a medium and a vacuum
8. PREVIEW FRAME So far you have learned that light moves in the form of waves which can travel through a vacuum and through certain media as well. How are light waves produced? The answers to this question are not completely known, even by the scientists who study light. In the following frames you will learn, in simple form, some of the basic facts that have been discovered about light. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

9.

Sound waves are produced when a body vibrates and sets other molecules in a medium in motion.

Light waves are produced when atoms lose certain amounts of energy. The energy is radiated, or given out in light waves.

Light waves are:

☐ different from sound waves
☐ the same as sound waves

different from sound waves

Light waves can travel:

☐ even if no molecules are set in motion
☐ only if molecules are set in motion

even if no molecules. . .

10.

Light waves are produced when atoms:

☐ gain, or absorb, energy
☐ lose, or radiate, energy

lose, or radiate, energy

11.

When atoms lose energy they radiate it in the form of electromagnetic waves. Radio waves and X-rays are forms of electromagnetic waves. When the energy loss of an atom is of a certain amount, the electromagnetic radiation is in the form of light.

Light is a form of electromagnetic radiation. All electromagnetic radiations have the same basic properties. Knowing this you can guess that all electromagnetic radiation can travel through:

☐ a medium only
☐ a vacuum only
☐ both a medium and a vacuum

both a medium and a vacuum

12. Sound waves can vary in frequency. Humans can hear sound waves of: ☐ all frequencies ☐ only some frequencies	only some frequencies
Electromagnetic waves can also vary in frequency. Radio waves, X-rays, and light are electromagnetic waves of different frequencies. They are produced by the loss of different amounts of energy by atoms. Humans can see: ☐ light waves ☐ sound waves ☐ X-rays	light waves
Humans can see electromagnetic radiations of: ☐ all frequencies ☐ only some frequencies	only some frequencies
13. Which of the following are electromagnetic waves? ☐ light waves ☐ radio waves ☐ sound waves ☐ X-rays	light waves radio waves X-rays
When atoms lose different amounts of energy they produce electromagnetic waves: ☐ of different frequencies ☐ of only one frequency	of different frequencies
Which of the following can travel through both a medium and a vacuum? ☐ light waves ☐ radio waves ☐ sound waves ☐ X-rays	light waves radio waves X-rays

14.

As a result of their investigations, scientists have found that certain characteristics of electromagnetic radiations make it necessary to think of these radiations as continuous waves which can travel through a vacuum. These findings are part of the *wave theory* of electromagnetic radiations.

When scientists studies other aspects of electromagnetic radiations they found that the energy in these radiations is emitted* from or absorbed by the atoms in discontinuous "packets" or "particles" of energy called *quanta*. These findings gave rise to the *quantum theory* of electromagnetic radiations.

The two theories seem to contradict each other. The wave theory states that electromagnetic radiations are in the form of *continuous waves* emitted by vibrating atomic particles. The quantum theory states that the energy in electromagnetic radiations is emitted in *discontinuous* "packets" or "particles". Although the theories seem to contradict each other, scientists use both theories to account for the properties of electromagnetic radiations.

The behavior of light is properly explained by:

☐ both quantum and wave theories
☐ the quantum theory alone
☐ the wave theory alone

both quantum and wave theories

---

*To *emit* means to give off.

15.	
All electromagnetic radiations can be thought of as continuous waves which can travel in a vacuum. This notion is part of the:	
☐ quantum theory of electromagnetic radiation ☐ wave theory of electromagnetic radiation	wave theory of . . .
Scientists have discovered that the energy of electromagnetic radiation is emitted or absorbed as:	
☐ continuous waves of energy ☐ discontinuous "packets" or "particles" of energy	discontinuous . . .
This finding is one of the bases for the:	
☐ quantum theory of electromagnetic radiation ☐ wave theory of electromagnetic radiation	quantum theory . . .
16.	
The wave theory of light explains certain aspects of light in terms of:	
☐ continuous waves which can travel through a vacuum	. . . can travel through . . .
☐ continuous waves which cannot travel through a vacuum	
The quantum theory of light explains certain aspects of light in terms of:	
☐ continuous waves of energy ☐ "particles" or bundles of energy	"particles" or bundles of energy

17. The energy of electromagnetic radiations is absorbed or emitted as quanta of energy. Another name for a quantum of electromagnetic energy is photon. A photon is a: ☐ "particle" of energy ☐ wave of energy	"particle" of energy
18. Scientists explain the properties of light in terms of: ☐ both the quantum and wave theories ☐ the quantum theory only ☐ the wave theory only	both the quantum and . . .
A photon is a "particle" of: ☐ energy ☐ matter	energy
19. FOOTNOTE FRAME The two theories of electromagnetic radiations, the wave theory and the quantum theory, are both necessary to explain the properties and behavior of the different electromagnetic radiations, including light. Because it is necessary to use two different theories to explain the various properties of light, people often refer to the dual nature of light. Actually, it is hard to say whether light has a single or a dual nature. We do know, however, that we have to use two different theories to explain the nature of light. Therefore, it is most accurate to refer to the dual nature of the theories of light. NO RESPONSE REQUIRED	GO ON TO THE NEXT FRAME

20.	
In their investigations of the behavior of light and other electromagnetic radiations scientists measure certain properties of these radiations.	
When light is studied as a type of wave phenomenon the measurements which are made are similar to those used for the study of other types of wave motion.	
Frequency is a measure which can be used to characterize:	
☐ all types of wave motion ☐ only some types of wave motion	all types of wave motion
Frequency is a measure which:	
☐ can be used to characterize light waves ☐ cannot be used to characterize light waves	can be used to . . .
21.	
The frequency of a light wave is a measure of the number of cycles per second in that light wave. Frequency is a measure which is used to characterize light waves.	
When scientists study how light energy is emitted from or absorbed by different substances, they measure the energy in terms of "particles" called photons.	
A photon:	
☐ is a quantum of light energy ☐ is not a quantum of light energy	is a quantum of light energy
A photon:	
☐ is a measure of the frequency of light waves ☐ is not a measure of the frequency of light waves	is not a measure of the . . .

22.

Frequency and measures of energy (quanta or photons) are measures used in the study of electromagnetic radiation. Though these measures are different, they are related. For example, it has been found that a quantum of X-ray radiation has more energy than a quantum of light radiation. It is also known that the frequency of X-ray radiation is higher than the frequency of light.

In this case the energy of a photon:

- ☐ decreases as the frequency of the radiation increases
- ☐ increases as the frequency of the radiation increases

increases as the frequency . . .

Here is another example: A photon of energy from radio waves has less energy than a photon from a light wave. Radio waves have lower frequencies than light waves.

In this case the energy in a quantum:

- ☐ decreases as the frequency of the radiation decreases
- ☐ decreases as the frequency of the radiation increases

decreases as the frequency . . .

23.

In general, the rule is that the energy of a photon or quantum is directly proportional to the frequency of the radiation.

As the frequency of electromagnetic radiation increases, the energy of a quantum of radiation increases.

As the frequency of electromagnetic radiation decreases, the energy in a quantum of radiation:

- ☐ decreases
- ☐ increases

decreases

24. Suppose we think of three types of electromagnetic radiations, A, B, and C. Suppose that all we know about these radiations is that the frequency of A is less than the frequency of B, and that the frequency of B is less than the frequency of C.	
Which has the highest frequency? ☐ A ☐ B ☐ C	C
A photon from the radiation with the highest frequency will have: ☐ less energy than a photon of either of the other two radiations ☐ more energy than a photon of either of the other two radiations	more energy than a photon . . .
Which of the three has the lowest frequency? ☐ A ☐ B ☐ C	A
A photon of the radiation with the lowest frequency will have: ☐ less energy than a photon of either of the other two radiations ☐ more energy than a photon of either of the other two radiations	less energy than a photon . . .
25. Light waves are electromagnetic radiations. If we measure the energy in the photons from two light waves of different frequencies we find that the photon with more energy comes from the light wave with the: ☐ higher frequency ☐ lower frequency	higher frequency

26. Visible light is one type of electromagnetic radiation. Visible light is made up of radiations of different frequencies. We can tell the difference between lights of different frequencies because different frequencies of visible light are seen by us as different colors. The frequency of red light is different from the frequency of blue light. Knowing this you can guess that the amount of energy in a photon of red light is: ☐ different from the amount in a quantum of blue light ☐ the same as the amount in a quantum of blue light	different from the . . .
27. Two lights of different color have: ☐ different frequencies ☐ the same frequencies The photons from lights of different color have: ☐ different amounts of energy ☐ the same amount of energy	different frequencies different amounts of energy

28. Have you ever seen a rainbow, or the colors on an oil slick or soap bubble? These colors are arranged in a certain order. At one end you see violet. This is followed, in order, by blue, green, yellow, orange and red. These colors make up the visible spectrum. We see a range of different colors in the visible spectrum. This is a result of the fact that the frequencies in different parts of that spectrum are: ☐ different ☐ the same	different
29. The visible spectrum is composed of: ☐ electromagnetic radiations of different frequencies ☐ electromagnetic radiations of one frequency only ☐ light of different colors ☐ light of one color only	. . . different frequencies light of different colors

30. The different colors in the visible spectrum are due to the range of different frequencies in the spectrum. The light of the lowest frequency in the visible spectrum is seen as a deep red color. The light of the highest frequency in the visible spectrum is seen as a violet color. The frequencies of different lights in the spectrum are arranged in an increasing order from red to violet. If the colors are arranged in the order red, orange, yellow green, blue, and violet, you can guess that light of a green color has a:	
☐ higher frequency than light of a yellow color ☐ lower frequency than light of a yellow color	higher frequency . . .
If you recall that the energy in a photon of light is proportional to the frequency of the light, you can also guess that a photon of green light has:	
☐ less energy than a photon of blue light ☐ more energy than a photon of blue light	less energy than . . .
31. The visible spectrum is only one small part of the complete spectrum of electromagnetic radiations. The human eye cannot see electromagnetic radiations that have higher frequencies than that of violet light, or lower frequencies than that of red light. Infrared radiation has lower frequencies than red light. Ultraviolet radiation has higher frequencies than violet light. Infrared and ultraviolet radiations:	
☐ are part of the spectrum of visible radiations ☐ are not part of the spectrum of visible radiations	are not part of the spectrum . . .

32.

radio waves	infrared rays	visible light	ultraviolet rays	X-rays

The diagram above is a representation of the spectrum of electromagnetic radiations, arranged from left to right in order of increasing frequency.	
Which have higher frequencies? ☐ infrared rays ☐ radio waves	infrared rays
Which have lower frequencies? ☐ ultraviolet rays ☐ X-rays	ultraviolet rays
What type of radiation has the lowest frequencies? ☐ infrared rays ☐ radio waves ☐ X-rays	radio waves
What type of radiation has the highest frequencies? ☐ infrared rays ☐ radio waves ☐ X-rays	X-rays
Visible light has frequencies which are higher than those of· ☐ infrared rays ☐ radio waves ☐ ultraviolet rays ☐ X-rays	infrared rays radio waves
Visible light has frequencies which are lower than those of: ☐ infrared rays ☐ radio waves ☐ ultraviolet rays ☐ X-rays	ultraviolet rays

33.

Which of the following are included in the spectrum of electromagnetic radiations?

- ☐ infrared rays
- ☐ radio waves
- ☐ sound waves
- ☐ ultraviolet rays
- ☐ visible light
- ☐ X-rays

infrared rays
radio waves

ultraviolet rays
visible light
X-rays

34.

MATCH the columns below to indicate the correct description of the terms given in the column on the right:

A. invisible radiation

B. measure of wave motion

C. "particle" of energy in electromagnetic radiations

D. visible radiation

1. _____ frequency
2. _____ infrared rays
3. _____ photon
4. _____ ultraviolet rays
5. _____ violet light
6. _____ X-rays

1. B
2. A
3. C
4. A
5. D
6. A

Time completed ______________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

	DEFINITION
THE TRANSMISSION OF LIGHT	Light is transmitted in the form of waves. Light can travel through some molecular media and through a vacuum.
THE PRODUCTION OF LIGHT	Light is produced when atoms lose certain amounts of energy which are given out or radiated in waves.
ELECTROMAGNETIC WAVES: The various frequencies of electromagnetic waves:	Waves are produced when atoms lose or radiate certain amounts of energy. Atoms losing different amounts of energy produce electromagnetic waves of different frequencies. Radio waves, X-rays, and light are electromagnetic waves of different frequencies. Of these, only light can be seen by the human eye.
THE DUAL NATURE OF LIGHT: The properties of light are explained by both the wave theory and the quantum theory. The theories seem to contradict each other, but no one theory alone adequately accounts for the properties of electromagnetic radiations.	The wave theory of light states that electromagnetic radiations behave as if they were in the form of continuous waves. The quantum theory of light states that electromagnetic radiations behave as if they were in the form of discontinuous particles of energy called quanta or photons.
Light can be measured by frequency and by the amount of energy of the photons.	The frequency of a light wave is a measure of the number of cycles per second in that light wave.
The relation between the frequency of a radiation and the energy of a radiation. Example: the frequency of X-rays is higher than the frequency of light and a quantum of X-ray radiation has more energy than a quantum of light.	The energy of a photon (or quantum) is directly proportional to the frequency of the radiation. In other words, as the frequency of electromagnetic radiation increases, the energy of a quantum of radiation increases; and as the frequency decreases, the energy decreases.
THE VISIBLE SPECTRUM	The visible portion of electromagnetic radiations (colors: red, orange, yellow, green, blue, and violet, ranging from low to high frequency, that is, from photons with less energy to photons with more energy).

	DEFINITION
INFRARED RADIATION (Radio Waves)	radiations that have lower frequencies than red light.
ULTRAVIOLET RADIATION (X-rays)	radiations that have higher frequencies than violet light.

MASTERY TEST

Time started ________________

1. Sound waves can travel through molecular media. Light waves, and other electromagnetic radiations:

   a. ☐ can travel only through a vacuum

   b. ☐ can travel through a vacuum and through some media

   c. ☐ cannot travel through any molecular media

2. Photons are:

   a. ☐ "packets" or light energy

   b. ☐ particles of matter

   c. ☐ waves of light energy

3. Frequency is a measure which is used to characterize the:

   a. ☐ absorption of energy from electromagnetic radiations

   b. ☐ emission of electromagnetic energy

   c. ☐ wave motion of electromagnetic radiations

4. The colors of the visible spectrum correspond to electromagnetic radiations of different frequencies. Which of the following is not included in the visible spectrum?

   a. ☐ green

   b. ☐ infrared

   c. ☐ red

   d. ☐ violet

Time completed ________________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 369-879

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ED 070909

ADVANCED GENERAL EDUCATION PROGRAM

A HIGH SCHOOL SELF-STUDY PROGRAM

THE BEHAVIOR OF LIGHT RAYS
LEVEL: II
UNIT: 9
LESSON: 12

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

U.S. DEPARTMENT OF LABOR
MANPOWER ADMINISTRATION, JOB CORPS
NOVEMBER 1969

1.

PREVIEW

In the preceding section you learned some basic facts about the nature of light and other electromagnetic radiations.

In the following section you will learn about some of the basic facts of the science which investigates the behavior of light. The findings of this science have been used to make many instruments, like cameras and microscopes, that depend on light.

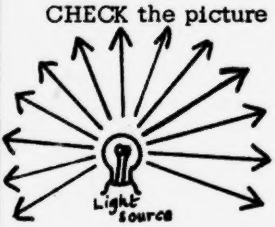
NO RESPONSE REQUIRED

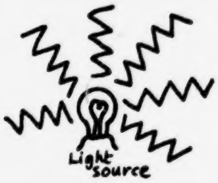
GO ON TO NEXT FRAME

2.

Light usually travels in straight lines. When scientists draw pictures of light, they represent its path by drawing a straight line called a ray.

CHECK the picture that shows light rays:


Light source


Light source

☐ A

☐ B

A

3.

When scientists represent the path of light by a line, that line is called a:

- ☐ particle
- ☐ ray
- ☐ wave

ray

4.

The branch of science that concerns itself with the visible light portion of the electromagnetic spectrum is called optics.

Which of the following is the science of optics concerned with?

- ☐ infrared radiation
- ☐ light
- ☐ radio waves
- ☐ ultraviolet radiation
- ☐ X-ray radiation

light

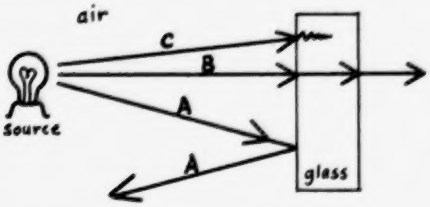
5.

Optics is the science concerned with:

- ☐ all wave phenomena
- ☐ the entire electromagnetic spectrum
- ☐ the visible light portion of the electromagnetic spectrum

the visible light portion of . . .

6.



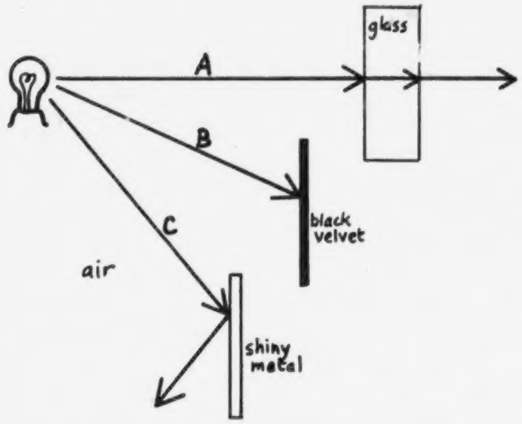
LOOK at the figure above.

The study of optics has led to the finding that when light strikes a surface between one medium and another or between a vacuum and a medium, there are three possibilities:

Ray A:	
☐ bounces off the surface	bounces off the surface
☐ passes through the surface and continues on	
☐ passes through the surface into a medium which absorbs it	
Ray B:	
☐ bounces off the surface	
☐ passes through the surface and continues on	. . . and continues on
☐ passes through the surface into a medium which absorbs it	
Ray C:	
☐ bounces off the surface	
☐ passes through the surface and continues on	
☐ passes through the surface into a medium which absorbs it	. . . which absorbs it

7.	
When light strikes a surface between one medium and another or between a vacuum and a medium, there are three possibilities: 1. The light can bounce back from the surface. This is called reflection. 2. The light can pass through the surface and continue on. This is called refraction. 3. The light can pass through the surface and into a medium where its energy is absorbed and the light disappears. This is called absorption.	
In which of the following is light changed so that it no longer can be seen? ☐ absorption ☐ reflection ☐ refraction	absorption
In which of the following is the direction of light reversed at the surface of a medium? ☐ absorption ☐ reflection ☐ refraction	reflection

8.


glass
A
B
C
black velvet
air
shiny metal

In the figure above, the light bulb is the source of light. Light travels from the bulb through air. Air is:	
☐ a medium	a medium
☐ a source	
Ray A is an example of:	
☐ absorption	
☐ reflection	
☐ refraction	refraction
Ray B is an example of:	
☐ absorption	absorption
☐ reflection	
☐ refraction	
Ray C is an example of:	
☐ absorption	
☐ reflection	reflection
☐ refraction	

9.

MATCH the following to indicate the correct description of each term in the right-hand column:

A. light bounces off the surface of a medium

B. light gives up its energy to a medium and disappears

C. light passes through a surface of a medium

D. path of light

1. _____ absorption

2. _____ ray

3. _____ reflection

4. _____ refraction

1. B

2. D

3. A

4. C

10.	
LOOK at Panel 1. (Page 14)	
In the figure in Panel 1, light from a source bounces off a surface.	
A represents a(n):	
☐ incoming ray	incoming ray
☐ reflected ray	
B represents a(n):	
☐ incoming ray	
☐ reflected ray	reflected ray
The dotted line is drawn at right angles to the surface at the point at which Ray A hits the surface. The dotted line:	
☐ is perpendicular to the surface	is perpendicular to the surface
☐ is not perpendicular to the surface	

11.

LOOK at Panel 1.

The dotted line in the figure is perpendicular to the surface at the point at which ray A hits the surface. Such a perpendicular is said to be normal to the surface. Sometimes it is called the normal to the surface at the point where it touches the surface.

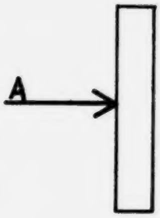
The angle between a normal to a surface and the point on the surface to which it is drawn is:

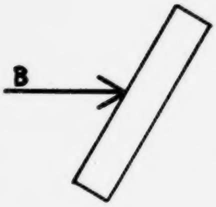
- ☐ a right angle
- ☐ less than a right angle
- ☐ more than a right angle

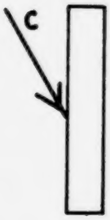
a right angle

12.	
A ray of light that strikes the surface of a medium at right-angles to the surface:	
☐ is not perpendicular to the surface	
☐ is perpendicular to the surface	is perpendicular to the . . .
Such a ray:	
☐ is normal to the surface	is normal to the surface
☐ is not normal to the surface	

13.







A ray of light that strikes the surface of a medium at right-angles to the surface is perpendicular to the surface. Such a ray is said to be normal to the surface.

LOOK at the diagrams above.

Which ray is normal to the surface which it strikes?

☐ A

☐ B

☐ C

A

14.	
LOOK at Panel 1.	
Ray A travels from the source to the surface. It is called the incident ray.	
Which is the angle between the incident ray and the normal to the surface?	
☐ angle I	angle I
☐ angle R	
Ray B is reflected from the surface. It is the reflected ray. The angle between the reflected ray and the normal is:	
☐ angle I	
☐ angle R	angle R

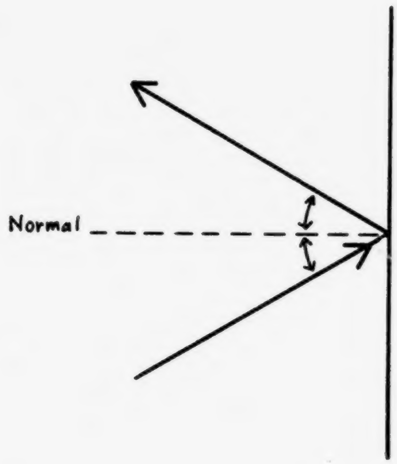
15.

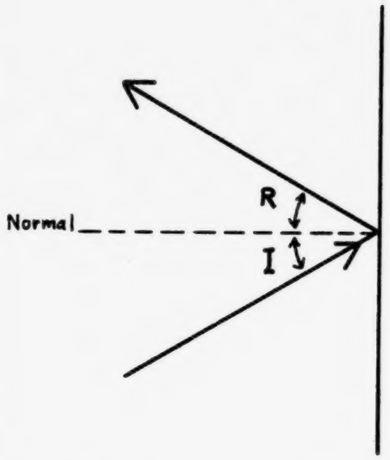
DO NOT LOOK at Panel 1.

The angle between the incident ray and the normal to the surface is called the angle of incidence.

The angle between the reflected ray and the normal to the surface is called the angle of reflection.

In the figure below LABEL the angle of incidence, I, and the angle of reflection, R.

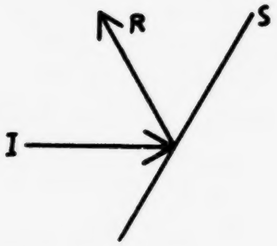




16.

In the figure below, I is an incident ray, R is a reflected ray, and S is a surface. In order to measure the angle of incidence and the angle of reflection it is necessary to draw the normal to the point at which I meets the surface.

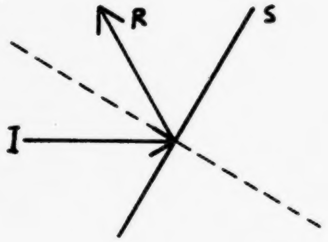
DRAW the normal to the point at which I meets the surface.



The normal to the surface is:

☐ parallel to the surface

☐ perpendicular to the surface



perpendicular to the surface

17.	
LOOK at Panel 1.	
What is the value, in degrees, of the angle of incidence?	
☐ 30°	30°
☐ 90°	
What is the value, in degrees, of the angle of reflection?	
☐ 30°	30°
☐ 90°	
The angle of incidence:	
☐ does not equal the angle of reflection	
☐ equals the angle of reflection	equals the angle of reflection

18.	
The angle of incidence equals the angle of reflection. This statement is the law of reflection.	
The angle of incidence is measured between an incident ray and the:	
☐ normal to the surface	normal to the surface
☐ surface	
The angle of reflection is measured between a reflected ray and the:	
☐ normal to the surface	normal to the surface
☐ surface	

19. The law of reflection states that the angle of reflection is: ☐ equal to the angle of incidence ☐ equal to twice the angle of incidence ☐ not equal to the angle of incidence	equal . . . angle of incidence

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20.

REVIEW

Light can travel through a vacuum and through:

- ☐ all media
- ☐ no media
- ☐ some media

some media

21.

A vacuum has no molecules or only very few molecules. Light travels through a vacuum with a speed of 186,000 miles per second.

When light travels through a molecular medium, like air, its speed is lower than its speed in a vacuum. The more dense the medium (the more molecules it has in each unit of volume), the slower the speed of light.

Air is:

- ☐ less dense than water
- ☐ more dense than water

The speed of light in air is:

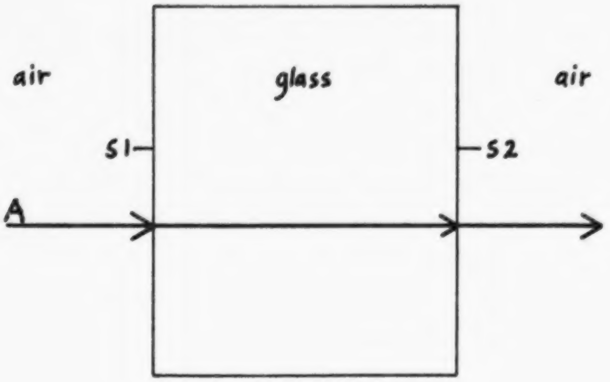
- ☐ greater than the speed of light in water
- ☐ less than the speed of light in water

less dense than water

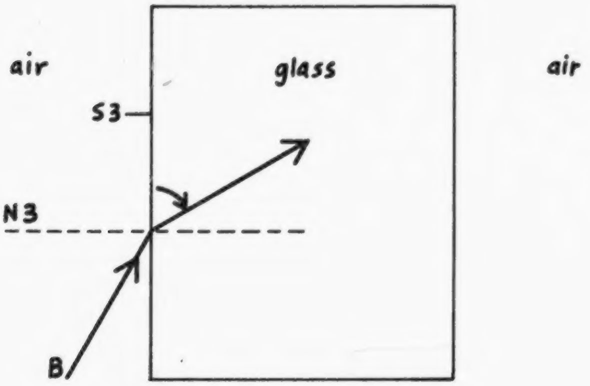
greater than the speed . . .

22.	
The more dense the medium in which light travels:	
☐ the faster its speed	
☐ the slower its speed	the slower its speed
When light passes from air to water its speed:	
☐ decreases	decreases
☐ increases	
When light passes from air to glass its speed:	
☐ decreases	decreases
☐ increases	
When light passes from glass to water its speed:	
☐ decreases	
☐ increases	increases
Suppose that a ray of light passes from any medium (or vacuum) through the surface of another medium. This is an example of:	
☐ absorption	
☐ reflection	
☐ refraction	refraction

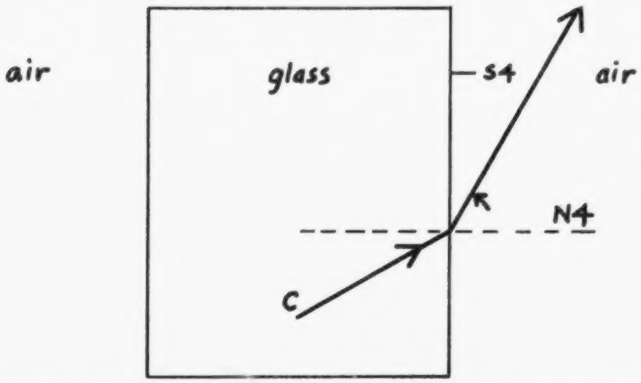
PANEL 2


air
glass
air
S1
S2
A

1.


air
glass
air
S3
N3
B

2.


air
glass
S4
air
N4
C

3.

23.	
REFER TO PANEL 2	
The figures in Panel 2 show three light rays, A, B and C, as they pass through air and glass.	
While it is in each medium (air or glass), each light ray travels in a line which: ☐ bends ☐ remains straight	remains straight
When the rays pass through the surface of a medium and continue on, that is an example of: ☐ absorption ☐ reflection ☐ refraction	refraction

24.	
LOOK at Panel 2.	
In figure 1, ray A passes from air through the surface, S1, of the glass. It then passes through the next surface, S2, of the glass into the air.	
Ray A is normal to:	
☐ both surfaces	both surfaces
☐ only surface S1	
☐ only surface S2	
As it is refracted through S1 and S2, ray A:	
☐ is bent	
☐ is not bent	is not bent
In figure 2, ray B passes from air through the surface, S3, of the glass. In figure 3, ray C passes from the glass through the surface, S4, to the air.	
Ray B is:	
☐ normal to S3	
☐ not normal to S3	not normal to S3
Ray C is:	
☐ normal to S4	
☐ not normal to S4	not normal to S4
Ray B is refracted through S3. Ray C is refracted through S4. Each ray:	
☐ is bent as it is refracted	is bent as it is refracted
☐ is not bent as it is refracted	

25.

LOOK at Panel 2.

Ray A is normal to the surfaces through which it passes.

Ray B is not normal to S3.

Ray C is not normal to S4.

According to the figures in Panel 2, a light ray is bent as it is refracted through the surface of a medium only if the ray is:

☐ normal to the surface

☐ not normal to the surface

not normal to the surface

26.	
LOOK at Panel 2.	
Ray B is not normal to surface S3. The normal to S3 is the dotted line N3.	
Ray C is not normal to surface S4. The normal to S4 is the dotted line N4.	
Ray B passes from a:	
☐ less dense to a more dense medium	less dense to a more dense . . .
☐ more dense to a less dense medium	
As it passes through the surface, ray B is bent:	
☐ away from the normal, N3	
☐ towards the normal, N3	towards the normal, N3
Ray C passes from a:	
☐ less dense to a more dense medium	
☐ more dense to a less dense medium	more dense to a less dense . . .
As it passes through the surface, ray C is bent:	
☐ away from the normal, N4	away from the normal, N4
☐ towards the normal, N4	

27.

DO NOT LOOK at Panel 2.

If a light ray is normal to the surface through which it passes, it will not be bent. This holds true whether the light is passing into a more dense or a less dense medium.

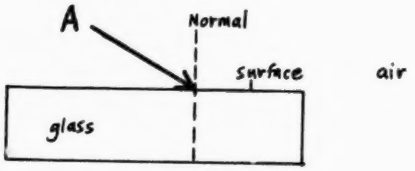
If a light ray is not normal to the surface through which it passes, there are two possibilities:

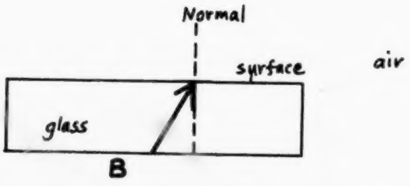
1. If the light passes from one medium into a more dense medium, it will be bent towards the normal.
2. If the light passes from one medium into a less dense medium, it will be bent away from the normal.

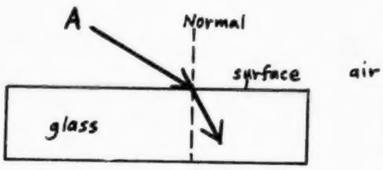
LOOK at the figures below.

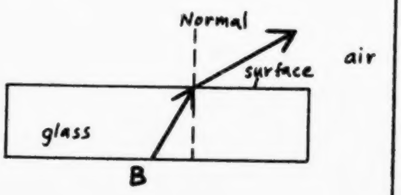
Ray A travels in air and strikes the surface of the glass. DRAW a continuation of the ray to show how it will be bent as it passes into the glass.

Ray B travels in glass and passes through the surface to the air. DRAW a continuation of the ray to show how it will be bent.

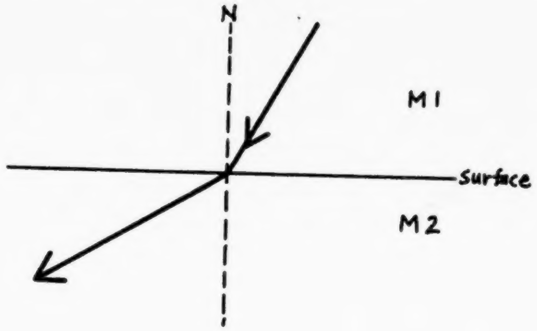

A
Normal
surface
air
glass


Normal
surface
air
glass
B


A
Normal
surface
air
glass


Normal
surface
air
glass
B

28.



In the figure above a ray passes from medium M1 to medium M2. In passing from M1 to M2 the ray:	
☐ is bent away from the normal ☐ is bent towards the normal	is bent away from the normal
This indicates that the ray is passing from one medium into a:	
☐ less dense medium ☐ more dense medium	less dense medium
Which is more dense?	
☐ M1 ☐ M2	M1

29.	
A ray of light passes from one medium to another. The ray is perpendicular to the surface of the medium into which it passes. The ray: ☐ is bent as it passes through the surface ☐ is not bent as it passes through the surface	is not bent as it passes . . .
A ray of light is bent towards the normal as it passes from medium M1 through the surface of medium M2. Medium M2 is: ☐ less dense than medium M1 ☐ more dense than medium M1	more dense than medium M1
When a ray of light passes from one medium to a less dense medium, the ray will be bent: ☐ away from the normal ☐ towards the normal	away from the normal

30.

MATCH the following:

A. ray is normal to a surface through which it passes

B. ray passes from a less dense to a more dense medium

C. ray passes from a more dense to a less dense medium

1. _____ bent away from normal

2. _____ bent towards the normal

3. _____ not bent in relation to normal

1. C

2. B

3. A

Time completed ________________

YOU HAVE NOW FINISHED THE FIRST PART OF THIS LESSON. WRITE DOWN THE TIME. THEN, AFTER YOU HAVE REVIEWED THE MAIN IDEAS IN THE FOLLOWING SUMMARY, TAKE THE MASTERY TEST AT THE END OF THE BOOKLET.

	DEFINITION
RAY	the path of light (usually represented by a straight line).
OPTICS	is the study of the visible light portion of the electromagnetic spectrum.
When light passes through a surface between one medium and another or between a vacuum and a medium, there are 3 possibilities:	
1. REFLECTION	the light bounces back.
2. REFRACTION	the light passes through the surface and continues on.
3. ABSORPTION	the light can give up its energy to the medium and, thus, disappear.
THE NORMAL	a ray of light that strikes the surface of a medium at right angles to the surface and is thus perpendicular to the surface.
THE INCIDENT RAY	is the ray from the source of light to the surface.
THE REFLECTED RAY	is the ray reflected from the surface.
THE ANGLE OF INCIDENCE	is the angle between the incident ray and the normal to the surface.
THE ANGLE OF REFLECTION	is the angle between the reflected ray and the normal to the surface.
THE LAW OF REFLECTION	states that the angle of incidence equals the angle of reflection.
If a light ray is normal to the surface through which it passes, it will not be bent.	This holds true whether the light is passing into a more dense or a less dense medium.

If a light ray is not normal to the surface through which it passes, it will be bent.

NOTE: Take the Mastery Test on Page 35.

DEFINITION

1. If the light passes from one medium into a more dense medium, it will be bent towards the normal.
2. If the light passes from one medium into a less dense medium, it will be bent away from the normal.

MASTERY TEST

Time Started: ______________________________

1. The science of optics is concerned with:

   a. ☐ all wave phenomena

   b. ☐ only the visible portion of the electromagnetic spectrum

   c. ☐ the entire electromagnetic spectrum

2. MATCH the following:

   A. light bounces off a mirror

   B. light gives up its energy to a medium and disappears

   C. light passes from air to water

   1. _____ absorption

   2. _____ reflection

   3. _____ refraction

3. The angle of incidence of a light ray striking a surface is measured between the incident ray and:

   a. ☐ a line parallel to the surface

   b. ☐ the normal to the surface

   c. ☐ the reflected ray

   d. ☐ the surface

4. The law of reflection states that the angle of reflection:

   a. ☐ always equals 45 degrees

   b. ☐ equals the angle of incidence

   c. ☐ equals twice the angle of incidence

5. As the density of a medium increases, the speed of light travelling in that medium:

a. ☐ decreases

b. ☐ increases

c. ☐ remains the same

6. Light travelling in air passes through the surface of a glass window. The light is perpendicular to the glass surface at the point where it enters. The light:

a. ☐ is bent away from the normal to the surface

b. ☐ is bent towards the normal to the surface

c. ☐ passes through the surface in a straight line

Time completed____________________

WHEN YOU HAVE FINISHED THIS TEST, WRITE DOWN THE TIME. THEN TAKE THE LESSON TO YOUR INSTRUCTOR OR HIS ASSISTANT FOR CHECKING. WAIT UNTIL THE LESSON IS APPROVED BEFORE GOING ON TO THE NEXT LESSON.

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